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ENERGETIC EFFICIENCY OF STEERS IN THE SUMMER AND WINTER IN RELATION TO THE CALIFORNIA NET ENERGY SYSTEM

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled " Energetic efficiency of steers in the summer and winter in relation to the California Net Energy System" submitted by Abdullatif I.H. Suleiman, in partial fulfilment of the requirements for the degree of Master of Science in Animal Nutrition (Beef cattle).

ABSTRACT

This experiment was designed to evaluate the usefulness of the California Net Energy System (CNES) for feedlot cattle in Alberta in the winter.

From 24 to 36 steers with an initial liveweight between 243 and 368 kg and of Hereford breeding were fed, individually or in pairs, an all-concentrate diet or a diet containing 25% wheat straw in each of two winter and two summer feeding periods during 1973, 1974 and 1975. The steers were offered the all-concentrate diet at one of three or four different feeding levels between 1.1 times maintenance and ad libitum. The diet containing wheat straw was fed at a level of approximately 1.4 times maintenance.

The steers fed all-concentrate diets gained more weight than predicted by the CNES in three of the four feeding periods ($P<0.05$) even though the actual energy gains were less ($P<0.01$) than predicted during two of these periods. This indicated that the steers tended to deposit proportionately less fat than expected for animals of this liveweight. Season did not have any consistent effect on the difference between predicted and actual gains.

The efficiency of use of digestible energy for gain for steers fed the all-concentrate diet was 32 and 27% for the two winter periods whereas the efficiency was 37 and 42% for the two summer periods. It was thus concluded that the efficiencies with which steers utilized energy intake in excess of maintenance was not constant as assumed in the CNES.

It could not, however, be concluded that this efficiency was reduced in a cold environment since the summer-fed steers deposited more of their energy as fat than winter-fed steers.

The efficiency of energy retention in liveweight gain (Y) was significantly ($P<0.05$) related to the percentage of energy retained as fat (X), according to the equation: $Y = -36.25 + 0.77X$, ($r^2=0.90$). This suggests that net energy for gain (NEg) values for feedstuffs are dependent on the type of depot tissue formed and thus upon the physiological age of the animal and the feeding level.

Results obtained in this study did not show any evidence that maintenance energy requirements for feedlot cattle are increased under Alberta winter conditions. These estimates, however, were obtained by extrapolation from results with steers fed above maintenance. Such animals would be expected to be affected by a cold environment to a lesser extent than cattle fed at maintenance.

No significant decreases in rates of gain, feed efficiencies, or energy retention due to feeding straw as compared to an all-concentrate ration was detected in any of the feeding periods.

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INTRODUCTION

There has been considerable interest and use recently of the California Net Energy System (CNES) which uses net energy values for predicting the performance and feed requirements of cattle. It has been argued that heat losses which occur during metabolism are accounted for by this system and therefore the CNES should be more accurate than the digestible, metabolizable or total digestible nutrient energy system (Moe and Tyrrell, 1973; Knox and Handley, 1973). The National Research Council has incorporated the net energy values from the CNES in its publication on beef cattle requirements (NAS-NRC, 1970) and has recently adapted the system for use with sheep (NAS-NRC, 1975).

One potential problem with the application of the system to Alberta conditions is the assumption that the maintenance energy requirement of cattle in winter is constant. Experimental results obtained by Young and Christopherson (1974) suggest that this assumption is not valid since maintenance requirements have been increased by 30 to 40% in cows exposed to cold. Similar trends were also observed with beef steers. Results obtained in feedlots have suggested that winter gains are less than summer gains relative to those predicted by the CNES (Milligan and Christison, 1974), which also indicates that environment may have a marked effect on animal requirements. Energy retentions have not been measured in feedlot studies however, and it is known that liveweight gain is not always a good predictor of energy

retention (Young,1975; Fox, 1976).

If cattle do suffer from cold stress in Alberta, then the heat which is produced by an animal during eating and metabolism of feed may be useful in keeping the animal warm (Kromann, 1973; Maynard and Loosli, 1969). Roughages have a higher heat increment of feeding than do grains (Blaxter, 1969), thus the CNES may under-estimate the value of roughages relative to grains for winter feeding.

This experiment was designed to evaluate the usefulness of the CNES for feedlot cattle under Alberta conditions and involved the measurement of energy retention by steers fed an all-concentrate diet at various feeding levels and a diet containing 25% straw at one feeding level during two summer and two winter feeding periods.

LITERATURE REVIEW

1.1 Need for a net energy system

Various energy systems have been used to evaluate the energy content of feedstuffs and animal requirements. Of these the total digestible nutrient (TDN) system has been used for the longest period of time in North America. One of the primary limitations of this system is that it does not account for some of the important energy losses in the animal such as the combustible gases, urinary losses and most importantly, the heat losses (Maynard and Loosli,1969; Crampton, 1956; Blaxter, 1967). The same is true of the digestible energy system (Maynard and Loosli, 1969).

Metabolizable energy (ME) values which account for gaseous and urinary energy losses are now also used in North America. Procedures employed in direct determination of ME are considerably more involved (and costly) than for the determination of TDN since estimation must be made of energy losses in gases and urine in addition to fecal losses. Recent estimates assign energy loss due to gaseous products of digestion at between 5 and 12% of gross energy (Kromann, 1973), with methane comprising 40% of the total gases produced in the rumen. Problems with the use of the ME system are that this system also does not account for heat losses. Also the proportion of gross energy lost in the urine and as methane decreases with increased feed intake (Blaxter, 1967). Furthermore, it has been indicated by Blaxter (1969) that methane production can also be altered by the quantity and type

of feed in the ration. More recently, Kennedy and Milligan (1978) have reported a lowered methane production (as a percentage of gross energy) in the rumen of sheep exposed to cold as compared to sheep kept in the warm. These factors would alter ME values of feeds. Because of difficulties in measuring methane production, actually determined ME values are available for few feeds and most ME values are calculated from digestible energy values.

A need for a system other than the TDN or metabolizable energy system has been expressed previously (Maynard and Loosli, 1969; Crampton _et al_, 1957; Garrett _et al_, 1959). Flatt (1965) reviewed results from practical feeding experiments with dairy cattle and discussed relative merits of TDN with other energy systems. It was concluded that the TDN system overestimates the productive values of roughages and low grade concentrates. Therefore, an estimated net energy system was considered more suitable for comparing values of forages and concentrates than the TDN system. Since a net energy value for a feedstuff refers to the actual amount of energy that the animal would retain if it was given a certain weight of the feed, and excludes the energy lost in feces, urine, gaseous products of digestion and as heat which is produced during the processes of eating, digesting and metabolizing the feed, it would be expected that net energy values would be more useful for predicting animal performance than would digestible or metabolizable energy values.

1.2 California net energy system

The California net energy system (CNES) which expressed net energy values for growing and finishing feedlot cattle was first introduced by Lofgreen (1963 a, b, c). A more detailed complete system was described by Lofgreen and Garrett (1968), separating the requirements for animals into two categories: net energy for maintenance (NEm) and net energy for gain or production (NEg). The system has gained wide acceptance, with the National Research Council first incorporating NEm and NEg values in its publication on beef cattle requirements (NAS-NRC, 1970). Recently, the system has been adapted for use with sheep (NAS-NRC, 1975).

1.2.1 Estimation of net energy content of feedstuffs

Liveweight gain as a measure of nutritive value of a feed can be misleading because cattle have different amounts of stomach fill (Fox *et al*, 1976). It would thus be more accurate to relate estimates of feed values to carcass composition and gain. This concept is very important in the application of the CNES. The net energy content of the dietary ingredients in the CNES is determined by a comparative slaughter technique which uses the specific gravity of the animal carcass to estimate the amount of feed energy actually retained as animal product. The method is based on the principle that the body is comprised of a fat-free body mass of constant gross composition and a variable quantity of fat (effectively a dilutant). The density of the fat-free body mass can thus be expected to be constant. Since

fat is lighter than water, muscle and bone (specific gravities of 0.92, 1.00, 1.06 and 1.50, respectively) (Kraybill et al, 1952) varying proportions of each will ascribe different values to body specific gravity.

In the Lofgreen California system, the body composition is calculated from the specific gravity of one-half of each carcass. Under water weights are made upon a chilled carcass (4°C) to minimize errors due to entrapped air. Any weight loss during chilling is assumed to be water. The weight in air is obtained on the warm carcass. Carcass specific gravity is then calculated from the equation:

$$\text{specific gravity} = \frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}}$$

The denominator will assume a large value with a 'fatter' carcass and result in an overall smaller specific gravity value for the carcass, as fat, being lighter than water, will cause a decrease in carcass weight in water.

Animal energy gain throughout the experimental period is determined as the difference between the empty body energy of an animal at the end of the trial and the calculated initial empty body energy of the animal which is obtained from information on an initial slaughter group. In this procedure, the empty body weight of the slaughtered animals is estimated from the equation: $Y = 1.36X + 30.26$ (Garrett and Hinman, 1969), where X = warm carcass weight and Y = empty body weight. Also the empty body energy (Mcal/kg) of each animal is estimated from the equation $Y = 47.480 - 41.886$ (carcass specific gravity). The total empty body energy of

each slaughtered animal is obtained by multiplying the respective empty body weight by the empty body energy value. Thus the net energy content of a feedstuff is calculated from the feed energy actually retained and the amount of feed supplied to achieve the gain.

1.2.2 Net energy requirements of animals

Lofgreen (1965), illustrated how net energy values were derived in the CNES. The total net energy of a feed is commonly expressed as 1) NE = ME - HI, where ME is metabolizable energy and HI is heat increment of feeding.

Total net energy of a given feed intake can also be shown as 2) NE = M + P, where M is the energy expended for maintenance and P is the net increase in energy of products such as new body tissue, milk, etc. The energy expended for maintenance is equal to the basal heat production (B) plus the heat of activity (A) thus:

$$3) \quad M = B + A$$

Equations 1 and 2 are equal and thus at a given feed intake M + P = ME - HI

By substituting for M, equation 4 is obtained:

$$4) \quad B + A + P = ME - HI$$

It is clear, therefore, that

$$B + A + HI = ME - P$$

or 5) HP = ME - P, where HP is total heat production and is equal to the sum of basal heat, heat due to activity and heat increment.

According to the CNES, to measure the NEm requirement it is necessary to know the HP of the fasting animal as this is the quantity of net energy that must be provided to keep the animal in energy equilibrium. HP at zero feed intake is estimated by measuring heat production over a range of intakes from maintenance to *ad libitum*. A logarithmic equation (log HP = 1.885 + 0.00166 ME) is then used to extrapolate to the HP at zero energy intake which is the fasting heat production (and at zero feed intake HI is zero). A plot of heat production/kg$^{.75}$ against ME intake/kg$^{.75}$ has shown that HP of fasting beef cattle is between 72 and 82 kcal/kg$^{.75}$, being similar for steers and heifers (Lofgreen and Garrett, 1968). This gives a mean value of 77 kcal/kg$^{.75}$. The average NEm requirement for cattle is thus considered to be 77 kcal per unit metabolic weight (kg$^{.75}$) and is used in the National Research Councils' recommendation for calculating NEm for beef cattle (NAS-NRC, 1970).

The net energy required for production (NEg) in the CNES has been determined as the gross energy of the products formed from consumption of a given amount of the ration above maintenance (Lofgreen, 1965 and Lofgreen and Garrett, 1968), suggesting that each succeeding increment of feed above maintenance has a constant NEg.

1.3 Problems with California net energy system

1.3.1 Validity of specific gravity technique

The usefulness of specific gravity or density measurement in predicting carcass composition has been reviewed by Pearson *et al*, (1968) and results from its application were discussed by Garrett (1968). Important in the use of specific gravity technique in estimations of carcass composition is the assumption that an animal can be divided into a two-compartment system of fat and fat-free body mass (Kraybill *et al*, 1952), with the fat-free portion having constant composition and hence a relatively constant density. Berg and Butterfield (1976), do not consider this assumption to be precisely true, but do agree that it is a fairly close approximation and produces reasonable estimates of fat and fat-free components in carcasses from animals over the range of normal slaughter weights. They have, however, reported decreases in water concentration and corresponding increases in protein and ash in the fat-free body mass of growing animals and differences in muscle to bone ratios between animals.

The validity of the specific gravity technique is of course dependent upon the accuracy with which it predicts the actual chemical composition of the animal. Very high simple linear relationships (r = 0.96 or higher) were obtained between the chemically determined components of the beef carcass and the empty body (ether extract, water, crude protein and energy [kcal/g]) and carcass density by the proponents

of the CNES (Garrett and Hinman, 1969). Standard errors of estimation associated with these correlations were relatively low (±0.09% [ash], ±0.53% [fat], ±0.74% [water], ±0.05% [nitrogen] and ±0.06% [energy]) indicating that carcass density is a good index of empty body or carcass composition of steers (Garrett and Hinman, 1969). The correlation coefficient of 0.96 between carcass density and percentage of empty body fat was almost identical with 0.956 reported by Kraybill _et al_, (1952). Also interestingly, the carcass density was seen to be more highly correlated with empty body parameters of ether extract, water, nitrogen and energy (kcal/g) than with the same parameters in the carcass. No explanation for this was given (Garrett, 1968). Stredwick (1972) in a detailed study involving comparisons between chemically determined water, fat and protein of bull carcasses and the same components calculated from the specific gravity measurements of the whole empty body found significant ($P<0.01$) linear correlations between the two procedures and concluded that the specific gravity technique gave good estimates of chemically determined values.

In addition to the claim for predictive accuracy, the specific gravity technique is supposed to be simple and can be easily determined on the commercially dressed carcass without incurring any monetary loss since the carcass remains intact and unharmed (Berg and Butterfield, 1976; Garrett, 1968). According to Garrett (1968), while the variation associated with predicting body or carcass composition from

specific gravity or density measurements is too high to be very precise in predicting the composition of individual carcasses, nevertheless, in experiments where replication is possible, the use of specific gravity can be valuable in demonstrating differences in body composition between groups. An additional possible advantage of the specific gravity technique is that the results do not seem to depend on the weight of the carcass (Garrett, 1968). Thus, if specific gravity technique could be demonstrated to be independent of sex and breed type also, it could be useful for general application to any kind of carcass (Berg and Butterfield, 1976).

There are some problems with the specific gravity technique, in relation to CNES, as discussed by Knox and Handley (1973). In net energy determinations one group of animals is fed at or near maintenance intake and others at level/s above maintenance, thus the low intake group finishes leaner while the other group/s become relatively 'fatter'. Reid and Robb (1971) have suggested that the precision of the specific gravity method might be lower for leaner animals than for fat ones. A study of the relationship between specific gravity and ether-extractable fat showed r^2 values of 0.21 when bone-free meat contained less than 10% fat and r^2 of 0.62 when fat content was over 40% (Kelly _et al_, 1968). This means that the prediction was better with fatter carcasses. Results of Gil _et al_, (1970), who chemically analysed and determined specific gravity on carcasses with 10-42% fat,

showed a significant ($P<0.01$) relationship between specific gravity and percent fat only in carcasses with 30 - 42% fat ($r^2 = 0.79$) also indicating better predictive accuracy with fatter carcasses.

1.3.2 Associative effects of feedstuffs

Associative effects between feedstuffs are known to affect the digestible and net energy value of feedstuffs. The usefulness of the CNES is thus limited to some extent by this interaction between feedstuffs.

Mitchell (1964) has emphasized that feeds and nutrients do not behave independently and has indicated that associative effects in ruminant digestion may be attributed to changes in the ratio of sugar and starch to nitrogen-containing compounds in the diet and, thus, the utilization of energy in a feed is a function of nutrient balance. The digestibility of combined ingredients in a ration may thus not be additive (Kromann, 1973) and the digestibility of the total ration may not necessarily be the weighted sum of digestibilities of the individual components. Kromann (1973) has suggested the use of simultaneous equations to define ingredient dependences in terms of effects on digestibilities and has demonstrated differences of approximately 10% in the digestible energy value for molasses as determined by this technique and one which assumed no associative effects between feedstuffs.

Blaxter (1956) has also observed that the associative effects of digestibility could not explain all of the increase in the net energy value of corn when added to a hay-containing

ration as compared to when it was added to a corn ration. He thus suggested that associative effects between feedstuffs also affected the heat increment of feeding and thus the net energy value of a feedstuff.

1.3.3 Validity of assuming a constant maintenance requirement

The maintenance requirement of a mature animal is the energy needed to keep the animal in a state in which body substance is neither gained nor lost and thus the animal is in energy equilibrium (Kleiber, 1961). Maintenance requirements can be estimated with fasting animals and expressed as a function of metabolic rate or fasting metabolism ($W^{.75}$kg). The equation 70 $W^{.75}$ kg (Kleiber, 1961) denotes the energy expended as heat by a fasting animal in a thermoneutral environment and (together with the 0.73 power proposed by Brody [1964]) is generally employed in predicting maintenance requirements. The CNES also assumes a constant NEm requirement of 77 kcal/$kg^{.75}$ irrespective of the level of production or energy gain (Lofgreen and Garrett, 1968).

These relationships, while they may account for most of the maintenance cost, may not be as constant as the equations imply. Age influences the animals' basal metabolism (Kleiber, 1961; Blaxter, 1967; Kromann, 1973), which is generally higher for immature or younger animals. Blaxter (1967) has reported differences in fasting metabolism between mature sheep and mature cattle: sheep having a 15% lower and cattle a 35% higher fasting metabolism than the interspecies mean of

70 kcal/kg$^{.75}$ (Kleiber, 1961). Differences in maintenance requirements also exist between breeds and within breeds of cattle (Blaxter, 1967).

Maintenance requirement includes the energy requirement for activity and maintaining body temperature (Kromann, 1973). Results of feeding trials (Mendel, 1966) with sheep suggest that maintenance requirements of sheep are lower under confinement than under natural environment. It has also been emphasized (Blaxter, 1967; Brody, 1964) that energy requirements may increase for range cattle. Garrett (1966) found that cattle required an additional 35 - 40 kilocalories of net energy per 45 kg (100 lbs) for every 1.6 km (1 mile) walked. Greenall (1959) indicated higher energy requirements for grazing wether lambs than the suggested standard values. Kromann et al, (1961), however, found no significant difference in energy requirements of steers grazing irrigated pastures compared to those fed in confined areas. Maintenance requirements for steers exposed to winter conditions are expected to be higher at low feeding levels (Hidiroglou and Lessard, 1971; Young, 1975b).

Knox and Handley (1973) and Kromann (1973) suggest that maintenance requirements are not likely to be constant when animals differ widely in rates of energy deposition. Dairy cow maintenance requirements have been shown to vary with the physiological processes occurring (Moe, Tyrrell and Flatt, 1971) since lactating cows have a higher (twice) maintenance requirement than the non-lactating cows (Hutton, 1962).

Flatt (1966) has also found increased maintenance requirements for dairy cows with increased production. Furthermore, increased maintenance costs or requirements as a result of increased production have also been reported in swine (Kotarbinska and Kielanowski, 1969). Kielanowski (1976) also suggested that animals synthesizing protein may have a higher maintenance requirement than animals synthesizing predominantly fat.

Estimates of maintenance energy requirements become important variables in determining energy requirements in the CNES since it has a considerable effect on the predictions of NEg. There is evidence that NEm is not constant as assumed in the CNES and thus a more precise assessment of the NEm requirements of cattle would be helpful in applying the CNES.

1.3.4 Nutritional deficiencies

The supply of essential nutrients other than energy may also affect net energy values of feedstuffs (Blaxter, 1956; Maynard and Loosli, 1969).

Mitchell (1964) found that when rats were fed rations varying in protein content from very low to very high levels, the efficiency of utilization of metabolizable energy did not increase continuously as the protein level increased: it increased initially, remained constant over a considerable range and then decreased as the protein level was raised above a certain critical level in the ration. The variable efficiencies of metabolizable energy utilization

were related to the changes in the heat increment of the rations fed: heat increment decreased as the protein content increased up to a level of 16-18%, remained generally constant for protein levels from 18 to 30 or 40% and then increased rapidly as the rations became increasingly richer in protein (up to 54% protein). The rations containing 18 to 30% protein had minimal 'specific dynamic action' or heat increment, were maximal in net energy content and promoted the most rapid growth in rats.

Earlier experiments with growing sheep also indicated that the net energy of a feed depended on the protein content of the diet (Blaxter, 1956). Similarly, Blaxter (1969) in discussing Møllgaard's experiment with cows observed that protein in excess of lactation needs was used with lower efficiency than the energy in a lower protein diet although fecal and methane energy losses were similar for both diets. The increased urinary energy associated with the high protein diet did not account for all of the decreased efficiency of energy usage.

Crampton, (1956) and Preston, (1966) suggest that there may be an optimum protein-energy ratio for the most efficient utilization of energy and a ration of 22 kcal of digestible energy per g of digestible protein is given to be the optimal ratio for growing-finishing lambs (Preston, 1966). Therefore it would appear that a deficiency or excess of protein that results in less than an optimum protein-calorie ratio for the respective physiological function, will increase the heat

increment of feeding (Kromann, 1973) and this would affect the efficiency of ME utilization and hence the estimates of net energy.

Deficiencies of minerals and vitamins can affect energy utilization within the animal (Blaxter, 1956; McDonald *et al*, 1969). Deficiencies of zinc in animal diets result in reduced growth rate and loss of appetite (Mills *et al*, 1969) and rapid cessation of growth (Underwood, 1977). An experiment by Miller *et al*, (1965) separated the effects of zinc deficiency *per se* from the indirect influence of reduced feed intake. Groups of calves were fed the control diets both *ad libitum* and in amounts restricted to somewhat less than the amount voluntarily consumed by the calves fed deficient diets. Zinc deficiency *per se* resulted in a lowered feed efficiency of 5.7 compared to 4.0 (kg feed/kg gain) for the restricted controls, indicating an approximate 42% reduction in feed efficiency in the zinc deficient calves. Comparable reduction in feed efficiency have also been demonstrated in pigs (Miller *et al*, 1968). The reduced feed efficiency in zinc deficiency, however, is not a result of lowered energy digestibility (Quarterman, 1968; Millet *et al*, 1966) but apparently to less efficient utilization of digested nutrients (Miller, 1970). This researcher has speculated that zinc deficiency results in impairment of enzyme(s) involved in the utilization of energy and this results in reduced energetic efficiency.

The phosphorus-deficient animal utilizes the food it

consumes less efficiently than a normal animal and this reduction has been attributed to a disturbance in energy metabolism that results from lack of adequate phosphorus in body cells and fluids (Underwood, 1966). McDonald et al, (1969) have reported a 10% reduction in efficiency of energy utilization in phosphorus deficient cattle, suggesting that phosphorus is important in the energy yielding reactions of intermediary metabolism.

The forgoing discussion gives some examples of how nutrient deficiencies can affect the net energy values of feedstuffs. The dependency of net energy values on other dietary ingredients thus represents a serious limitation to the accuracy of net energy values determined on feedstuffs.

1.3.5 Environmental effects

1.3.5.1 Effects of a cold environment on digestion

The digestibility of feeds has been shown to decrease when sheep are exposed to cold environmental temperatures (Graham et al, 1959; Graham, 1964; Westra and Christopherson, 1976; Ames and Brink, 1977). Similar results have also been reported for cattle (Blaxter and Wainman, 1961; Young and Christopherson, 1974; Christopherson, 1976). Moose et al, (1969), however, has reported little or no effect of prolonged cold exposure on energy digestibility in sheep with controlled feed intakes (concentrates). Fuller and Cadenhead (1969) showed that changes in digestibility were not attributable to differential microbial fermentation rates of feces between time of voiding and collection, as was earlier suggested by Graham et al, (1959). Some of the latter studies also

showed that reduced digestibility in the cold was not related to temperature effects on appetite or feed intake.

A decrease in the mean retention time of the digesta in the alimentary tract of animals exposed to cold has been reported by Warren et al, (1974) and Westra and Christopherson (1976), with the latter authors reporting greater frequency of reticular contractions in sheep. These factors may thus be associated with the observed reduced digestibilities in the cold since digestibility was found to be directly related to the mean retention time of digesta in the rumen as well as in the whole digestive tract (Westra, 1975).

Recently, Kennedy et al, (1976) found a decreased organic matter digestibility in the rumen and an increased efficiency of microbial synthesis which indicates a beneficial effect of cold on protein metabolism. Methane production rates (and hence energy losses) have also been reported to be lower in the rumen of the cold exposed animals (Kennedy and Milligan, 1978) which compensates to some degree for reduced energy digestibility. Environmental conditions would thus appear to affect the digestible and metabolizable energy and thus the net energy content of a feedstuff.

1.3.5.2 Effects of a cold environment on metabolic rate and animal performance

An important physiological change that accompanies exposure to cold environmental temperatures is the reduction in the lower critical temperature in sheep and cattle (Graham et al, 1959; Webster et al, 1969; Young 1973). Webster et al, (1970) has estimated the lower critical temperature of steers, feeding at maintenance level, to be

-20°C and that of reasonably sheltered feeder cattle in latter stages of growth to be -30°C (Webster, 1970). Below the lower critical temperature, an animal increases its heat production (metabolic rate) to meet the increased thermal demand from the environment (Young and Christopherson, 1974; Webster, 1976); thus more of the energy intake is channeled towards maintaining the animal and less energy is available for production. The increased metabolic rate is generally advanced as the primary factor causing losses in production efficiency in livestock in cold environments.

Sheep acclimated to cold environmental temperature have shown increased resistance to cold stress and an increased resting oxygen consumption (Webster et al, 1969). Two types of metabolic responses observed by Slee (1974) in sheep adequately summarise these effects of cold. Firstly, there is an increased heart rate at thermoneutrality after exposure to cold. Secondly, there is a response of an elevated peak metabolic rate capability in sheep which have previously been exposed to cold as shown by an increased resistance to body cooling on exposure to acute cold for 2 to 8 hours. Type of prior cold exposure determines the duration of both responses to cold. An elevated potential peak metabolic rate in sheep exposed to acute cold persisted till about 8 weeks after return to a thermoneutral environment while the same response of sheep following chronic cold treatment disappeared after 2-4 weeks. On the other hand, the increased resting metabolic rate as a consequence of either chronic or acute cold exposure was seen to be retained only for 8 days.

Beef cows on exposure to chronic low temperatures were reported (Young 1975) to have retained the increased resting metabolic rate for approximately 2 weeks.

Young and Christopherson (1974) have pointed out the importance of distinguishing the short term direct effects of cold on metabolism and the long term adjustments involving acclimatization. Increases in metabolism (higher metabolic rate) even when cold stress is absent would increase maintenance requirements. This energy expenditure would considerably adversely affect efficiency of energy utilization of animals and thus the net energy value of feedstuffs.

Several studies reviewed by Gonyou (1977) demonstrate adverse effects of cold environments on efficiency of production. Webster _et al_, (1970) in an experiment with 12 cattle reported a drop in efficiency (in terms of weight gains) in cold exposed cattle and a further drop in cattle that were cold exposed and not provided with shelter. Similarly, sheep kept inside consuming the same amounts of feed as unsheltered animals, gained 62% more in body weight than the unsheltered group (Webster _et al_, 1969). Hidiroglou and Lessard (1971) reported that for similar feed intakes, steers wintered outside gained 30% less liveweight over a period of 168 days compared to the steers housed in an unheated barn.

In contrast to these results Webster (1970) from a study involving 108 measurements and 24 cattle ranging in weight from 140 to 335 kg concluded that feedlot cattle in colder regions of Canada, when reasonably sheltered (heating not

included), were exposed to temperatures below their lower critical temperatures for only very short periods of time each year and therefore the effect of cold on efficiency of production would be insignificant. Effects of cold on pregnant cows and younger animals were expected to be significant but not excessive since the estimated losses in efficiency of production were considered to be relatively small.

Consideration of data from large numbers of cattle fed in different seasons also indicates that winter cold may affect animal performance. A 20 month Colorado study (Knox and Handley, 1973), undertaken to evaluate the CNES, used data from over 95,000 steers and heifers and predicted gains calculated from feed consumption records. The study showed that the actual weight gains during the winter months were 15% lower than predicted. The summer cattle, however, gained up to 35% more than predicted. The effective mean monthly temperatures, corrected for wind, moisture and temperature, ranged from -20°C to 10°C with the winter environment greatly reducing feed efficiency.

Milligan and Christison (1974) analysed 6 years of monthly feedlot data at Saskatoon, Saskatchewan, to determine the effects of climate on steer performance. Data used was from 1970 yearling steers which were provided only with wind protection. Regressions of daily weight gain and feed to gain ratio on temperature were statistically significant being 0.014 kg/day and -0.067 feed/gain respectively per 10°C increase in

environmental temperature. In contrast to Webster's (1970) results, then, these studies suggest that full-fed feedlot cattle are adversely affected by prairie winters and thus the CNES may not be applicable in cold environments. Studies relating weight gain to environmental effects must be viewed with caution, however, since weight gains may not adequately reflect energy gains in animals.

EXPERIMENTAL

2.1 Objectives

The objectives of the study were:

1) To evaluate the usefulness of the California Net Energy System for cattle under Alberta winter conditions where maintenance requirements may be increased, and

2) To determine if the relatively high heat increment of feeding which occurs when straw is fed is useful in keeping an animal warm in the winter .

2.2 Experimental design and diets

Four lots of steers of Hereford breeding were used in four experimental feeding periods conducted during the summers of 1973 and 1974 and the winters of 1973-1974 and 1974-1975. The 30 to 42 animals used in each season were ranked according to weight into five to seven groups, then one steer from each weight group was randomly assigned to each dietary treatment and to an initial slaughter group so that there were six animals per treatment.

In the 1973 summer study each group of six steers was further subdivided into three groups of approximately the same total weight. The two animals in each group were then fed together in one of 15 pens. During the following winter six steers were held in each of four

pens and the animals were again fed in pairs of equal liveweight while being confined in adjacent stanchions. In the 1974-1975 trial, steers were individually fed while in stanchions in four pens. An additional six steers were fed *ad libitum* as a group in one pen in the summer of 1974 and as a group in each of two pens during the 1974-1975 winter trial.

An initial group of six steers (five in summer of 1973) was slaughtered at the start of each test period and the total empty body weight, empty body energy and fat content of these steers was measured. The remaining steers were fed either an all-concentrate diet (Table 1) to provide 1.4, 1.7 or 2.0 times the amount of energy required for maintenance or a 25% wheat straw and 75% concentrate diet fed at approximately 1.4 times maintenance. An additional group of steers was fed an all-concentrate diet at 1.1 times maintenance in the summer of 1973 and either one or two groups of steers were fed this diet on *ad libitum* basis during the last two feeding periods of summer 1974 and 1974-1975 winter.

The maintenance level of feeding was calculated to be 36 g of dry matter per $kg^{.75}$ per day for the all-concentrate diet by using the net energy for maintenance (NEm) values for barley and animal requirements as given in the NAS-NRC (1970) nutrient requirement tables. The amount of concentrate and straw offered in the 1973 summer and 1973-1974 winter feeding periods was restricted to an amount

Table 1. Ingredients and composition of experimental diets

	Year			
	1973-1974		1974-1975	
	All-concentrate diet	25% straw diet	All-concentrate diet	25% straw diet
Ingredients %				
Straw	-	25	-	25
Barley, dry-rolled	97.0	72.8	96.9	72.7
Calcium carbonate[1]	1.0	0.8	1.3	1.0
Calcium phosphate[2]	0.5	0.4	0.2	0.2
Urea (45%N)	1.0	0.8	1.0	0.8
Trace mineralised salt[3]	0.5	0.4	0.5	0.4
Vitamin A, D and E[4]	+	+	+	+
Chemical composition (analysed)				
Dry matter (%)	85.1	85.9	86.7	87.1
Crude protein (%)[5]	14.5	13.6	12.2	11.7
Gross energy (Mcal/kg)[5]	4.3	4.3	4.4	4.4
Crude fibre (%)[5]	5.5	14.4	5.1	14.2
Organic matter (%)[5]	93.9	94.3	94.1	94.4

[1]The calcium carbonate contained 35% Ca.

[2]Commercial product containing 18.5% Ca and 20.5% P.

[3]The trace mineralised salt contained 96.5% NaCl, .400% Zn, 0.120% Mn, .160% Fe, 0.033% Cu, 0.004% Co and .007% I.

[4]To supply 5000, 830 and 5 I.U. of vitamins A, D_3 and E respectively, per kg of diet in 1973-1974 and twice this amount in 1974-1975.

[5]Dry matter basis.

equal the consumption of the steers with the lowest *ad libitum* intake. In the last two feeding periods the 25% - straw ration was limit-fed to provide an energy intake of 1.4 times maintenance. The feed intake of all steers at restricted levels of feeding was kept constant relative to metabolic weight throughout the test periods by adjusting the feed offered according to the weekly weights of the steers. The all-concentrate diets were prepared at the University of Alberta feedmill while the wheat straw was prepared at the experimental site by chopping with a New Holland Forage harvester. In addition to the basal feeds all animals had free access to trace mineralised salt and a 1:1 mixture of trace mineralised salt and calcium phosphate.

At the end of the feeding period animals were slaughtered and carcass specific gravity, empty body energy and empty body composition were determined and energy retention throughout the trial was calculated. Efficiency of use of digestible energy intake above maintenance for gain was also calculated.

The 155 day feeding period in the summer of 1973 was from April 17 to September 18 and the 146 day winter period started on November 21 of the same year and finished on April 15, 1974. The 110 day summer feeding period in 1974 commenced on May 29 and concluded on September 15. The final wintering trial was conducted in a 92 day period

between January 5 and April 6, 1975.

2.3 Description and management of experimental animals

All animals were purchased from a commercial firm for this study, were of Hereford breeding and weighed between 243-368 kg. Most steers appeared to be yearlings, although the animals used in 1974-1975 winter feeding period were noticeably younger than those used in the other periods. Upon arrival at the Beef Cattle Nutrition Unit at the Ellerslie Research Station the steers were held in a 4 x 8 m pens which were partially covered by an open-front shed. They were given long hay for one to two weeks after their arrival. Trace mineralised salt and 1:1 mixture of trace mineralised salt and calcium phosphate were also available on a free-choice basis. All animals were vaccinated for blackleg, malignant edema and received a 2 ml intra-muscular injection containing 1,000,000 I.U. of Vitamin A, 150,000 I.U. of Vitamin D_3 and 100 I.U. of Vitamin E. After the settling in period all steers were given increasing daily amounts of the all-concentrate diets over a 2-week period until the maximum assigned level of concentrate feeding for the trial was reached at which time the experiment was started.

Water was available *ad libitum* from heated water bowls throughout the study except at the time of confinement for feeding and prior to weighing. Steers were offered half their ration twice daily and were allowed 2 to 3 hours each morning and afternoon to consume the given feed. Wood

shavings were used for bedding. The steers were weighed at weekly intervals throughout the experiment and on two consecutive days at the start and the end of the experiment. All the weights were taken in the morning before feeding and after water had been withheld for 16 hours.

2.4 Environmental data

Metereological data was obtained for the experimental periods from the Government of Canada Atmospheric Environment Service at the Edmonton International Airport located within 15 km of the experimental site (Environment Canada, 1973, 1974 and 1975). Routine checks of daily minimum and maximum temperatures indicated that there was little variation between the airport temperatures and those recorded in the animal pens. Daily mean temperatures were calculated as the average of the maximum and minimum for each day. Degree days, as a measure of cold stress, were obtained by adding the number of degrees the mean daily temperature was below -20°C during the trial period and dividing the total by the number of days in the period (Dietz, 1971). The value of -20°C was used since it approximates the likely lower critical temperature of a steer at the maintenance feeding level (Webster *et al*, 1970).

2.5 Predicted liveweight gains

Predicted liveweight gains were obtained using the 1970 NAS-NRC tables by calculating the net energy for gain (NEg) available in the ration at each level of feeding by first subtracting the feed required to provide the net energy for maintenance requirements.

2.6 Carcass measurements

The steers were slaughtered on the final day of test at a commercial abbatoir and the warm weight of the carcasses was recorded. The carcasses were graded by Federal Government graders who also made measurements of rib eye area and average backfat depth from readings at the top, middle and bottom of the eye muscle between the 11th and 12th ribs. The dressing percentages for each carcass were calculated by expressing the warm carcass weight as a percentage of final weight on test.

2.7 Empty body weight and composition

Empty body weight (weight of the whole animal minus digestive tract contents) was estimated using the equation: $Y = 1.36X + 30.26$ derived by Garrett and Hinman (1969) where X is the warm carcass weight and Y is the empty body weight. Empty body energy and fat content of the steers was estimated by specific gravity techniques (Garrett and Hinman, 1969). The left side of each carcass was chilled for 48 hours at 4°C and then weighed in air to the nearest 0.22 kg (0.5 lb) and under 4°C water in a large cylindrical (diameter 150 cm; height 200 cm) tank to the nearest gram. The specific gravity of a carcass was obtained from the weight in air and the weight in water using the following equation:

$$\text{carcass specific gravity} = \frac{\text{weight in air}}{\text{weight in air-weight in water}}$$

Empty body energy of steers was calculated by the

equation: Empty body energy (kcal/g = 47.58 - 41.97X, where X = carcass specific gravity (Garrett and Hinman, 1969). The amount of fat in the empty body of the steers was calculated using the equation: % ether extract(fat) = 551.38 - 498.50X, where X = carcass specific gravity (Garrett and Hinman, 1969). Total energy in the fat of each animal was calculated by multiplying the fat weight by the factor of 9.385 kcal/g (Harris, 1970).

Empty body weight, energy and fat content of each steer in the initial slaughter group was divided by the animal's liveweight to obtain the average initial empty body weight, energy and fat content per kg of liveweight. These average values were used to calculate the initial empty body composition of each of the remaining steers in the experimental groups. Total empty body weight, energy and fat gain for each animal in the experimental groups was thus calculated as the difference between the final and calculated initial empty body weight, energy and fat contents.

2.8 Digestibility measurements

The 1973 summer digestibility measurements were made using a combination of total collection and grab sample techniques. Total collection of excreta from the actual experimental steers was accomplished by scraping the concrete floor of the pens daily over a 7-day period. Measurements at the 1.1 times maintenance level, however, were obtained from steers held in metabolism crates. A representative 5% aliquot of the total amount of excreta collected was ob-

tained for each collection day. The acid detergent-fibre content of this material was determined and the total acid detergent fibre excreted was calculated. Grab samples, also taken throughout the total collection period, were then analysed for acid detergent fibre, dry matter, energy, ash and protein. The total amount of nutrients in the fecal material collected over the 7-day period was thus calculated from the following equation:

$$\text{kg of acid detergent fibre collected} \times \frac{\text{concentration of nutrient in grab samples}}{\text{concentration of acid detergent fibre in grab samples}}$$

Digestibility measurements of dry matter, organic matter, energy and nitrogen were subsequently calculated. Since similar grain and straw were used in the 1973-1974 winter feeding period, digestibility measurements were not made during this time.

Four Hereford steers, housed at the Metabolic Research Unit on the Parkland Farm were used to determine digestibility coefficients for 1974-1975 diets. In the first part of the digestibility study, all four steers were individually fed a 25% wheat straw and 75% concentrate diet. Subsequently, each steer was individually fed an all-concentrate diet at one of the three feeding levels in a modified Latin Square design, having the same two of the four steers feeding at one of the levels each time. A three-week feeding period, involving a two-week adjustment period and a 7-day fecal

collection period was used. Total fecal output was collected in bags as described by Hoogendoorn and Grieve (1969) with the bags being changed once daily. A 5% aliquot of daily fecal production was frozen and saved for analysis.

Digestibility of the winter 1974-1975 all-concentrate diet was determined using four steers fed at a level of 1.7 times maintenance. The steers were held on an elevated wooden platform while being restrained individually in stanchions. Total collection was achieved using large plastic collecting trays placed under each of the steers at the ground level. An electric wire ran behind each steer to assure proper standing posture when the feces were voided into the trays.

Fecal samples were dried at between 103-105°C for 24 hours for dry matter determinations. Daily samples from the steers were composited to make one sample for each steer. Each combined sample was finely ground using a Christy-Norris grinding mill and stored in a plastic bag inside a plastic bag.

2.9 Chemical analysis

Dry matter, crude protein and ash content of feed and fecal samples were determined by using the Association of Official Agricultural Chemists (1965) methods. Gross energy of feed and feces samples was determined by combustion in a Parr oxygen bomb calorimeter. Acid detergent fibre content of feed and feces was determined by the method of Goering and Van Soest (1970).

2.10 Statistical analysis

In the digestibility studies conducted with the steers fed the all-concentrate diet in the summer of 1974 the data obtained with the two steers fed at the same feeding level each time were averaged to give one value. This was done to obtain an equal number of observations (three) for each level of feeding for the two years. A two-way analysis of variance was done on data from these digestibility trials (Table 4).

In the feeding trials in the summer of 1973 and winter of 1973-1974 average values for each pair of steers fed together were used in statistical analysis since feed intake records were not available for each individual animal. Thus in the 1974 summer and 1974-1975 winter studies data from two steers were also combined to obtain three observations per mean for each parameter considered in Tables 5 and 6.

Analysis of variance and regression analysis were performed (Steel and Torrie, 1960) using programs available from the University of Alberta Computing Centre. Duncan's New Multiple Range Test (Steel and Torrie, 1960) was used in comparison of means. In cases of missing data averages of observations were used to obtain equal number of observations per mean. The degrees of freedom were accordingly reduced by one in such cases in the analysis of variance tests. Predicted and actual rates of gain were compared with the paired t - test (Steel and Torrie, 1960). Homogeneity of regression equations (Table 6; Figures 1-4) were determined according to procedures given in Steel and Torrie (1960).

RESULTS

3.1 Environmental conditions

Meteorological data obtained for the experimental period included mean temperatures, mean maximum and mean minimum temperatures, number of days and number of degree days the temperature was below -20°C and relative humidities (Table 2). Wind data was not measured because of the large variation which would have existed within and between pens and also because wind effects were considerably reduced as a result of wind protection provided to the steers by the shed and surrounding corrals.

The mean temperatures recorded throughout the winter and summer feeding periods (Table 2) could be considered normal for the experimental site since 13 year average temperatures (1961 to 1974) for the months of December through March and May through August were -12°C and 13°C, respectively. The number of degree days of cold stress was 53 in the winter of 1973-1974 compared to 34 in the shorter feeding period of 1974-1975 winter (Table 2). There were six occasions of 2-4 days duration in the 1973-1974 winter and four occasions of 2-3 days duration in the 1974-1975 winter when the mean temperature fell below -30°C. The mean relative humidities for the four feeding periods were comparable (Table 2).

3.2 Characteristics of initial slaughter group

The liveweight of the cattle slaughtered at the start of each of the four periods differed significantly ($P<0.05$),

Table 2. Mean, mean maximum and minimum temperatures, number of days and degree days the temperature was below -20°C and relative humidities during the experiments

Experimental period	Feeding period (days)	Mean temp.[1] (C)	Mean max. temp. (C)	Mean min. temp. (C)	Days mean temp. below -20°C	Degree days[2] below -20°C	Mean relative humidity[3] (%)
Summer, 1973	155	12.5	19.2	6.0			68
Winter, 1973-1974	146	-12.7	- 7.1	-18.3	47	53	69
Summer, 1974	110	13.3	19.8	6.7			75
Winter, 1974-1975	92	-12.6	- 6.8	-18.5	33	34	66

[1]Mean from daily maximum and minimum temperatures.

[2]Cumulative number of degrees the mean daily air temperature was below -20°C divided by number of days in the feeding period.

[3]Based on four daily measurements at 0500, 1100, 1700 and 2300 hours.

with the group fed in the 1973-1974 winter heavier than other groups and the 1974-1975 winter-fed group lighter (Table 3). No significant differences (P>0.05) were detected in carcass specific gravities or dressing percentages between the four groups of steers. Significant differences (P<0.05) which existed between warm carcass weights and empty body weights (Table 3) could be attributed to differences in liveweight between cattle in the four feeding periods.

The group of steers slaughtered at the start of the 1973-1974 winter feeding period had the highest carcass specific gravity (Table 3). Thus, even though they were the heaviest of all initial slaughter groups they contained less amount of fat than the lighter 1974 summer steers (Table 3). There were no significant differences (P>0.05) in empty body weight, energy and fat content of the initial slaughter groups of steers when these were expressed on a per kg of liveweight basis (Table 3).

3.3 Animal health

All of the animals remained generally healthy throughout the experimental periods. Some problems were encountered, however, in maintaining feed consumption at the assigned level during the 1974-1975 winter feeding period, and some of the animals had to be given hay to stimulate appetite. Results from these steers and any that consumed less than 95% of the assigned level of feed, have been excluded from the data presented in Tables 5 to 8.

Table 3. Means and standard errors of liveweight, carcass data and empty body parameters for the initial slaughter groups

	Feeding period				
	1973 Summer	1973-1974 Winter	1974 Summer	1974-1975 Winter	Standard error
No. of steers	5	6	6	6	
Liveweight (kg)	303^{b}	362^{a}	322^{b}	265^{c}	10.66
Carcass specific gravity	1.074^{a}	1.080^{a}	1.071^{a}	1.077^{a}	0.003
Warm carcass weight (kg)	167.9^{b}	197.5^{a}	175.6^{b}	141.5^{c}	6.25
Dressing %	55.3^{a}	54.5^{a}	54.5^{a}	53.5^{a}	0.95
Empty body weight (kg)	259^{b}	299^{a}	269^{b}	223^{c}	8.52
Empty body fat (kg)	41.9^{ab}	39.1^{ab}	47.1^{ab}	32.1^{b}	4.34
Empty body energy (Mcal)	650.2^{ab}	675.9^{a}	705.7^{a}	526.3^{b}	42.97
Empty body energy/kg live weight (Mcal)	2.150^{a}	1.854^{a}	2.191^{a}	2.002^{a}	0.13
Empty body weight/kg live weight (kg)	0.854^{a}	0.826^{a}	0.836^{a}	0.840^{a}	0.01
Empty body fat/kg live weight (kg)	0.138^{a}	0.108^{a}	0.146^{a}	0.121^{a}	0.01

$^{a-c}$Similar superscripts in the same row indicate values that are not significantly different (P>0.05).

3.4 Apparent digestibility of dietary components

Apparent digestibilities for the different diets and years are given in Table 4. Values for the 1.1 times maintenance feeding level were not included in the statistical analysis since no steers were fed at this level except in the 1973 summer feeding period.

Dry matter digestibilities were 77.2, 74.8, 74.8 and 67.0% and organic matter digestibilities were 80.2, 78.5, 78.6 and 69.2% for the all-concentrate diet fed at the 1.4, 1.7, 2.0 times maintenance feeding level and the 25% wheat straw diet, respectively (Table 4). The dry and organic matter digestibilities in the all-concentrate diets were thus not affected by the level of feeding ($P>0.05$) while in the straw diets dry and organic matter were not digested as well ($P<0.05$) as in all-concentrate diets. Level of feeding had no significant ($P>0.05$) effect on the apparent digestibilities of crude protein in the steers fed the all-concentrate diets nor was there any significant difference ($P>0.05$) in the digestibility of protein between the all-concentrate diets and the diet containing straw (Table 4).

The apparent digestibilities of gross energy for the steers at 1.4 times and 1.7 times maintenance level of feeding were not significantly ($P>0.05$) different from each other while the mean for 2 times maintenance level was significantly ($P<0.05$) lower than the 1.4 times maintenance level (Table 4). There was a drop of approximately 1.7 digestibility units with each increase of 0.3 times maintenance in feed intake

Table 4. Means and standard errors of apparent digestibilities (%) of dry matter, gross energy, crude protein and organic matter of diets offered at various feeding levels

	Level of Feeding (times maintenance)						Year		
	1.1[1]	1.4	1.7	2.0	1.4 (25% straw diet)	Standard error	1973	1974	Standard error
Dry matter	72.3	77.2[a]	74.8[a]	74.8[a]	67.0[b]	0.90	76.2[a]	70.73[b]	0.63
Gross energy	73.3	78.5[a]	76.8[ab]	75.3[b]	67.8[c]	0.89	77.0[a]	72.2[b]	0.63
Crude protein	73.2	77.7[a]	73.5[a]	72.8[a]	72.0[a]	1.52	77.3[a]	70.7[b]	1.07
Organic matter	76.3	80.2[a]	78.5[a]	78.6[a]	69.2[b]	0.90	79.4[a]	73.8[b]	0.64

[1]Only measured in 1973 and not included in statistical analysis.

[a-c]Similar superscripts in the same row indicate values that are not significantly different ($P>0.05$).

level for the all-concentrate diets. The digestibility of energy for the steers fed the 25% straw diet was significantly ($P<0.05$) lower than that with the all-concentrate diets (Table 4).

There were significant differences ($P<0.05$) in apparent digestibilities of dry matter, organic matter, crude protein and gross energy of all the diets between the years (Table 4), being generally 5 digestibility units lower in 1974 compared to 1973.

Digestibility measurements were also conducted for the all-concentrate diet fed at the 1.7 times maintenance in the winter of 1974-1975. Apparent digestibilities for dry matter, gross energy, crude protein and organic matter were 71.8, 73.9, 69.1 and 75.0% respectively and were not significantly ($P>0.05$) different from the values obtained in the previous summer, although they were generally 2 digestibility units higher.

3.5 Feedlot performance and carcass data

Average daily gains for all steer groups increased as the feeding level increased (Table 5). The steers fed in the 1973 summer period gained faster than other groups at all feeding levels, although this difference was only significant ($P<0.05$) at the 2 times maintenance feeding level and when the 25% straw diet was fed (Table 5). Digestible energy intake was, however, significantly ($P<0.05$) higher in the 1973 summer-fed group (Table 5). Rib eye area at slaughter also tended to be larger in the 1973 summer group

Table 5. Means and standard errors of feedlot performance data and carcass characteristics of experimental steers

	Feeding Period				
	1973 Summer	1973-1974 Winter	1974 Summer	1974-1975 Winter	Standard error
	All-concentrate diet, 1.4 x maintenance				
No. of steers	6	6	5	4	
Dry matter intake (g/kg $^{.75}$/day)	48^{a}	49^{a}	49^{a}	49^{a}	0.64
Digestible energy intake (kcal/kg $^{.75}$/day)[1]	164^{b}	168^{ab}	171^{a}	163^{b}	1.59
Initial weight (kg)	301^{c}	337^{a}	323^{b}	253^{d}	3.49
Final weight (kg)	373^{b}	389^{a}	362^{c}	289^{d}	3.00
Daily gain (kg)	0.46^{a}	0.36^{a}	0.36^{a}	0.39^{a}	0.03
Daily feed intake[2] (kg)	4.5^{b}	4.8^{a}	4.5^{b}	3.8^{c}	0.03
Feed/gain[2]	9.8^{b}	13.5^{a}	12.6^{ab}	10.5^{ab}	1.04
Warm carcass weight (kg)	205^{b}	223^{a}	193^{c}	154^{d}	3.51
Dressing %	55.1^{ab}	57.2^{a}	53.3^{bc}	52.0^{c}	0.69
Fat depth (mm)	6.7^{a}	8.3^{a}	5.6^{ab}	2.7^{b}	1.14
Rib eye area (cm^2)	65.3^{a}	54.6^{b}	51.1^{b}	47.6^{b}	2.29
	All-concentrate diet, 1.7 x maintenance				
No. of steers	6	6	6	5	
Dry matter intake (g/kg $^{.75}$/day)	58^{a}	59^{a}	60^{a}	59^{a}	0.53
Digestible energy intake (kcal/kg $^{.75}$/day)[1]	203^{a}	203^{a}	196^{b}	192^{b}	1.74
Initial weight (kg)	304^{c}	339^{a}	323^{b}	258^{d}	3.09
Final weight (kg)	413^{a}	413^{a}	387^{b}	320^{c}	3.43
Daily gain (kg)	0.71^{a}	0.50^{c}	0.59^{b}	0.70^{a}	0.02
Daily feed intake[2] (kg)	5.7^{b}	5.9^{a}	5.6^{b}	4.8^{c}	0.03
Feed/gain[2]	8.1^{c}	11.7^{a}	9.6^{b}	6.9^{d}	0.35
Warm carcass weight (kg)	227^{b}	242^{a}	206^{c}	171^{d}	3.44
Dressing %	54.9^{b}	58.7^{a}	53.3^{b}	53.3^{b}	0.70
Fat depth (mm)	5.9^{b}	12.1^{a}	11.3^{a}	4.5^{b}	1.57
Rib eye area (cm^2)	64.7^{a}	59.6^{ab}	59.4^{ab}	51.6^{b}	2.68
	All-concentrate diet, 2 x maintenance				
No. of steers	6	6	6	4	
Dry matter intake (g/kg $^{.75}$/day)	74^{a}	71^{a}	69^{a}	68^{a}	0.25
Digestible energy intake (kcal/kg $^{.75}$/day)	256^{a}	245^{b}	221^{c}	213^{d}	0.79
Initial weight (kg)	300^{c}	342^{a}	319^{b}	256^{d}	2.64
Final weight (kg)	462^{a}	461^{a}	412^{b}	339^{c}	5.09
Daily gain (kg)	1.04^{a}	0.81^{b}	0.85^{b}	0.91^{b}	0.04
Daily feed intake[2] (kg)	7.6^{a}	7.6^{a}	6.7^{b}	5.7^{c}	0.03
Feed/gain[2]	7.2^{bc}	9.4^{a}	8.0^{b}	6.3^{c}	0.37
Warm carcass weight (kg)	264^{b}	273^{a}	224^{c}	186^{d}	2.86
Dressing %	57.2^{b}	59.1^{a}	54.4^{c}	54.5^{c}	0.38
Fat depth (mm)	6.8^{b}	14.4^{a}	13.8^{a}	4.9^{b}	1.12
Rib eye area (cm^2)	63.2^{a}	64.8^{a}	57.6^{b}	56.9^{b}	1.35

[1]Obtained from measured digestibility coefficients at each feeding level.

[2]As-fed basis.

[a-d]Similar superscripts in the same row indicate values that are not significantly different ($P>0.05$).

(Table 5, cont'd)

	1973 Summer	1973-1974 Winter	1974 Summer	1974-1975 Winter	Standard error
			All-concentrate diet, ad-libitum		
No. of steers			12	6	
Dry matter intake ($g/kg^{.75}/day$)			94	78	
Digestible energy intake ($kcal/kg^{.75}/day$)[1]			301[a]	244[b]	0.75
Initial weight (kg)			321[a]	251[b]	2.62
Final weight (kg)			473[a]	338[b]	12.72
Daily gain (kg)			1.38[a]	0.95[a]	0.11
Daily feed intake[2] (kg)			9.7	6.3	
Feed/gain[2]			7.0	6.7	
Warm carcass weight (kg)			267[a]	192[b]	0.12
Dressing %			56.6[a]	56.6[a]	0.24
Fat depth (mm)			16.1[a]	9.6[b]	1.41
Rib eye area (cm^2)			61.3[a]	57.3[a]	2.14
			25% straw diet		
No. of steers	6	6	5	5	
Feeding level (times maintenance)	1.47	1.62	1.40	1.36	
Total dry matter intake ($g/kg^{.75}/day$)	61[b]	67[a]	58[bc]	56[c]	1.04
Concentrate (g $DM/kg^{.75}/day$)	46	50	43	42	
Wheat straw (g $DM/kg^{.75}/day$)	15	17	15	14	
Digestible energy intake ($kcal/kg^{.75}/day$)[1]	188[b]	206[a]	167[c]	161[c]	3.17
Initial weight (kg)	300[b]	336[a]	322[a]	256[c]	5.67
Final weight (kg)	414[a]	400[a]	359[b]	299[c]	8.14
Daily gain (kg)	0.74[a]	0.44[b]	0.34[b]	0.47[b]	0.06
Daily feed intake[2] (kg)	5.9[b]	6.7[a]	5.3[c]	4.4[d]	0.05
Feed/gain[2]	7.9[b]	15.5[a]	16.0[a]	10.1[b]	1.47
Warm carcass weight (kg)	237[a]	229[a]	193[b]	161[c]	4.35
Dressing %	57.2[a]	57.1[a]	53.7[b]	53.9[b]	0.48
Fat depth (mm)	7.1[b]	11.9[a]	7.2[b]	3.1[c]	0.74
Rib eye area (cm^2)	66.5[a]	55.7[bc]	58.3[ab]	47.0[c]	3.14

[1]Obtained from measured digestibility coefficients at each feeding level.

[2]As-fed basis.

[a-d]Similar superscripts in the same row indicate values that are not significantly different ($P>0.05$).

(Table 5). This group of steers and those fed in the 1974-1975 winter period also had the best feed conversion efficiencies ($P<0.05$) at the 1.7, 2.0 levels of feeding (Table 5). The trend towards a greater efficiency of feed utilization in the 1974-1975 winter-fed steers occured even though they ate the least amount of digestible energy relative to metabolic weight (Table 5). The greater efficiency of feed utilization of this group was related to their relatively lower initial liveweights, dressing percentages and fat depth at the time of slaughter (Table 5).

The inclusion of wheat straw in the diet appeared to improve the feedlot performance of the steers fed in the summer of 1973. In this period average daily gains and feed efficiencies with this diet compared favourably with those obtained when the all-concentrate diet was fed at the higher feeding level of 1.7 times maintenance (Table 5). No improvement in feedlot performance due to straw, however, could be detected in the other three feeding periods.

The significantly ($P<0.05$) improved feedlot performance of the 1974 summer steers at full feeding level in average daily gain compared to the 1974-1975 winter steers at full feed is related to the 20% more feed the summer group consumed relative to metabolic weight compared to the winter group (Table 5).

3.6 Empty body composition and energy gain

Carcass specific gravities were lower in the animals at the end of the feeding periods as compared to the initial

slaughter groups (Tables 3 and 6). No significant (P>0.05) differences were detected in carcass specific gravities between treatment groups or feeding level at the 1.4 and 1.7 times maintenance level of feeding (Table 6). Final empty body fat and energy content were lower (P<0.05) in 1974-1975 winter than in the other feeding periods and were due to lower final empty body weights of steers for this feeding period (Table 6). At higher feeding levels the steers slaughtered in the 1974-1975 winter had the highest (P<0.05) specific gravities and contained the least fat and energy (Table 6). This was also related to their lower final weights and reflected by their relatively low average backfat depth (Table 5).

There were no differences (P>0.05) in empty body energy gain (kcal/kg$^{.75}$/day) between the steers fed all-concentrate diets at similar feeding levels during the four seasons (Table 6); however, as expected, there was more energy gained as level of feeding was increased. The daily fat gained by the 1974-1975 winter-fed steers was significantly less (P<0.05) than the fat gained by steers fed in other feeding periods at the 2.0 times maintenance level of feeding. Steers fed the 25% straw diet in the 1974-1975 summer and winter gained less energy (P<0.05) than those fed similarly in the previous two seasons (Table 6). This was due to a lower feed and energy intake (Table 5).

Results from steers feeding at 1.1 times maintenance level in 1973 summer were (appendix Tables1a,b and 2) not

Table 6. Means and standard errors of empty body composition and gain of experimental steers

	Feeding period				
	1973 Summer	1973-1974 Winter	1974 Summer	1974-1975 Winter	Standard error
	All-concentrate diet, 1.4 x maintenance				
No. of steers	6	6	5	4	
Carcass specific gravity[1]	1.066[a]	1.077[a]	1.068[a]	1.073[a]	0.002
Initial empty body weight (kg)	257.1[b]	278.2[a]	269.9[a]	212.5[c]	2.92
Initial empty body fat (kg)	41.6[b]	36.7[c]	47.5[a]	30.6[d]	0.49
Initial empty body energy (Mcal)	647.8[b]	624.0[c]	707.5[a]	506.3[d]	6.72
Final empty body weight (kg)	292.6[b]	333.7[a]	293.2[b]	239.9[c]	7.13
Final empty body fat (kg)	58.3[a]	49.3[a]	51.5[a]	34.9[b]	2.62
Final empty body energy (Mcal)	826.5[a]	798.3[a]	803.7[a]	569.7[b]	27.23
Gain empty body weight ($g/kg^{.75}/day$)	2.9[a]	4.5[a]	2.7[a]	4.4[a]	0.62
Gain empty body fat ($kcal/kg^{.75}/day$)	12.8[a]	9.9[a]	8.6[a]	6.7[a]	2.14
Gain empty body energy ($kcal/kg^{.75}/day$)	14.7[a]	14.2[a]	11.1[a]	10.3[a]	2.11
Energy gain as fat (%)	87	70	77	65	
	All-concentrate diet, 1.7 x maintenance				
No. of steers	6	6	6	5	
Carcass specific gravity[1]	1.066[a]	1.070[a]	1.067[a]	1.075[a]	0.002
Initial empty body weight (kg)	259.3[c]	280.4[a]	270.2[b]	215.3[d]	2.66
Initial empty body fat (kg)	42.0[b]	36.9[c]	46.7[a]	31.0[d]	0.41
Initial empty body energy (Mcal)	653.1[b]	628.8[c]	708.2[a]	512.9[d]	6.58
Final empty body weight (kg)	339.3[b]	360.3[a]	311.4[c]	262.7[d]	4.62
Final empty body fat (kg)	68.9[a]	66.1[a]	60.3[a]	41.0[b]	3.29
Final empty body energy (Mcal)	969.7[a]	970.1[a]	865.0[a]	646.7[b]	31.14
Gain empty body weight ($g/kg^{.75}/day$)	6.2[a]	6.3[a]	4.6[b]	7.5[a]	0.40
Gain empty body fat ($kcal/kg^{.75}/day$)	19.7[a]	21.7[a]	14.1[a]	14.8[a]	3.74
Gain empty body energy ($kcal/kg^{.75}/day$)	24.6[a]	27.1[a]	17.4[a]	21.0[a]	3.50
Energy gain as fat (%)	80	80	81	70	
	All-concentrate diet, 2 x maintenance				
No. of steers	6	6	6	4	
Carcass specific gravity[1]	1.056[b]	1.065[b]	1.058[b]	1.076[a]	0.003
Initial empty body weight (kg)	256.0[c]	282.9[a]	266.7[b]	215.1[d]	2.12
Initial empty body fat (kg)	41.4[b]	37.3[c]	46.1[a]	30.9[d]	0.34
Initial empty body energy (Mcal)	644.8[b]	634.6[b]	699.2[a]	512.4[c]	5.33
Final empty body weight (kg)	389.7[b]	401.6[a]	335.4[c]	283.6[d]	4.01
Final empty body fat (kg)	97.1[a]	83.1[a]	81.2[a]	43.0[b]	5.68
Final empty body energy (Mcal)	1264.5[a]	1160.7[ab]	1068.2[b]	687.5[c]	49.95
Gain empty body weight ($g/kg^{.75}/day$)	10.0[ab]	8.9[b]	7.4[c]	10.5[a]	0.35
Gain empty body fat ($kcal/kg^{.75}/day$)	39.1[a]	32.3[ab]	35.7[a]	17.3[b]	4.57
Gain empty body energy ($kcal/kg^{.75}/day$)	46.3[a]	39.6[a]	40.0[a]	26.9[a]	4.27
Energy gain as fat (%)	84	82	89	64	

[1]Measured at 4°C.

[a-d]Similar superscripts in the same row indicate values that are not significantly different ($P>0.05$).

(Table 6 cont'd)

	1973 Summer	1973-1974 Winter	1974 Summer	1974-1975 Winter	Standard error
			All-concentrate diet, ad-libitum		
No. of steers			12	6	
Carcass specific gravity[1]			1.052[b]	1.070[a]	0.002
Initial empty body weight (kg)			268.2[a]	210.8[b]	2.25
Initial empty body fat (kg)			46.9[a]	30.3[b]	0.35
Initial empty body energy (Mcal)			594.3[a]	502.2[b]	11.46
Final empty body weight (kg)			394.4[a]	291.2[b]	10.09
Final empty body fat (kg)			107.1[a]	52.6[b]	5.95
Final empty body energy (Mcal)			1358.3[a]	780.5[b]	60.87
Gain empty body weight ($g/kg^{.75}/day$)			12.9[b]	12.4[a]	1.10
Gain empty body fat ($kcal/kg^{.75}/day$)			57.7[a]	32.0[a]	6.76
Gain empty body energy ($kcal/kg^{.75}/day$)			78.0[a]	42.8[b]	6.93
Energy gain as fat (%)			74	75	
			25% straw diets		
No. of steers	6	6	5	5	
Carcass specific gravity[1]	1.061[c]	1.066[bc]	1.069[ab]	1.077[a]	0.002
Initial empty body weight (kg)	255.7[b]	277.6[a]	268.8[ab]	215.1[c]	4.68
Initial empty body fat (kg)	41.4[b]	36.6[c]	46.5[a]	31.0[d]	0.67
Initial empty body energy (Mcal)	643.9[b]	622.6[b]	704.5[a]	512.6[c]	11.01
Final empty body weight (kg)	353.1[a]	341.9[a]	292.6[b]	251.3[c]	5.77
Final empty body fat (kg)	79.0[a]	69.0[b]	54.4[c]	36.0[d]	2.66
Final empty body energy (Mcal)	1070.5[a]	973.3[b]	794.0[c]	590.0[d]	22.05
Gain empty body weight ($g/kg^{.75}/day$)	7.6[a]	5.1[b]	2.7[c]	5.8[ab]	0.57
Gain empty body fat ($kcal/kg^{.75}/day$)	27.8[a]	24.4[a]	8.5[b]	7.6[b]	2.82
Gain empty body energy ($kcal/kg^{.75}/day$)	32.9[a]	28.1[a]	10.2[b]	12.3[b]	2.46
Energy gain as fat (%)	85	87	83	62	

[1]Measured at 4°C.

[a-d]Similar superscripts in the same row indicate values that are not significantly different ($P>0.05$).

included in Tables 5 and 6 since there were no data to compare against in the other three periods.

3.7 Actual vs predicted liveweight and energy gains

Actual average daily gains for the four feeding periods tended to be higher than the gains predicted by the California Net Energy System (Table 7); in the case of the 1973 summer and 1974-1975 winter steers fed the all-concentrate diet this difference was significant at the $P<0.01$ level. The actual rates of gain of steers fed the 25% straw diets, although generally higher, were not significantly ($P>0.05$) different from the predicted rates of gains with the exception of the 1974-1975 winter steers which grew faster than predicted ($P<0.05$).

While the rates of gain tended to be generally greater than those predicted by the California Net Energy System, the actual energy gains (Mcal/day) were less ($P<0.01$) than the predicted values in the case of 1974 summer and 1974-1975 winter steers fed all-concentrate diets (Table 7). The daily energy gains for steers fed the 25% straw diets were higher than predicted for the 1973 summer (Table 8), although not significantly ($P>0.05$) so. The data from steers fed at 1.1 times the maintenance level in the summer of 1973 were included in the information given in Tables 7 and 8 and Figures 1 to 4.

3.8 Relationship between digestible energy intake and liveweight gain

The relationship between digestible energy intake and liveweight gain for the steers fed all-concentrate diets were

Table 7. Actual minus predicted rates of gain and energy retention of steers

	Summer[1,2] 1973	Winter[1,2] 1973-1974	Summer[1,3] 1974	Winter[1,3] 1974-1975
All-concentrate diets				
Rate of gain (kg/day)	0.17±0.01**	0.03±0.02	0.06±0.02*	0.15±0.03**
Energy gain (Mcal/day)	-0.25±0.12	0.04±0.19	-0.69±0.22**	-0.88±0.17**
25% straw diets				
Rate of gain (kg/day)	0.25±0.09	-0.03±0.06	0.10±0.07	0.21±0.06*
Energy gain (Mcal/day)	0.93±0.08	0.13±0.06	-0.46±0.21	-0.22±0.18

[1] Means ± standard errors.

[2] Steers were fed in pairs.

[3] Steers were fed individually.

* $P<0.05$.

** $P<0.01$.

Table 8. Linear regressions[1] of liveweight gains ($g/kg^{.75}/day$) on digestible energy intake ($kcal/kg^{.75}/day$) for steers fed all-concentrate diets

Feeding period	Regression	X-axis intercept	Number of observations	r^2	Standard error[2]
Summer, 1973	$Y=-7.4 + 0.08X^b$	92	12	0.99	0.45
Winter, 1973-1974	$Y=-6.2 + 0.06X^c$	103	9	0.94	0.46
Summer, 1974	$Y=-10.2 + 0.08X^b$	128	18	0.81	1.17
Winter, 1974-1975	$Y=-11.1 + 0.10X^a$	111	13	0.77	1.45

[1] Linear regression of the type $Y = a + bx$.

[2] Standard error of estimate.

[a-c] Linear regression coefficients with different superscripts are significantly different ($P<0.05$).

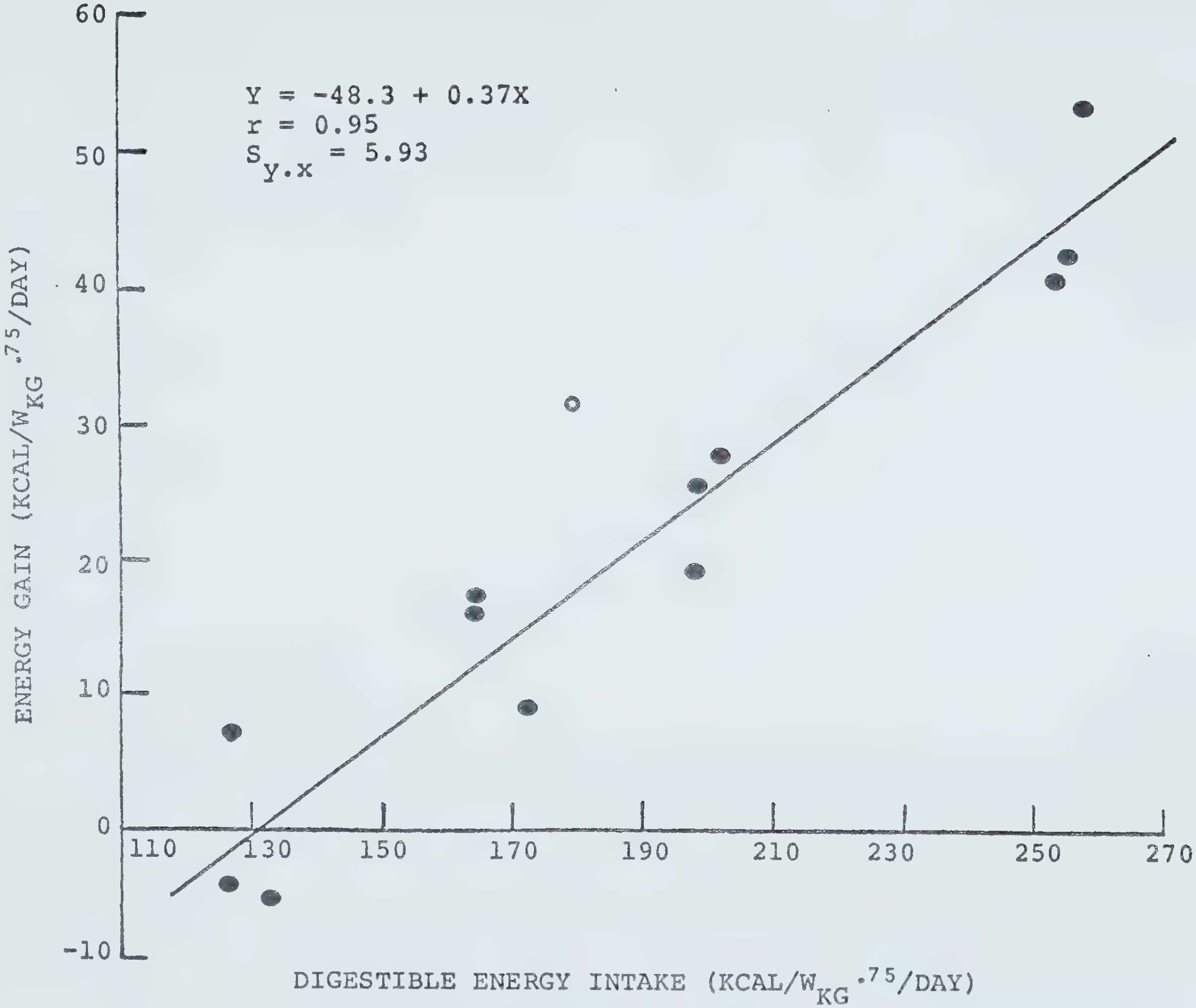

Figure 1. The relationship between energy gain and digestible energy intake during the 1973 summer feeding period. Each point represents data from two steers. The circle (o) is an average value for the 25% straw group and was not considered in the regression equation.

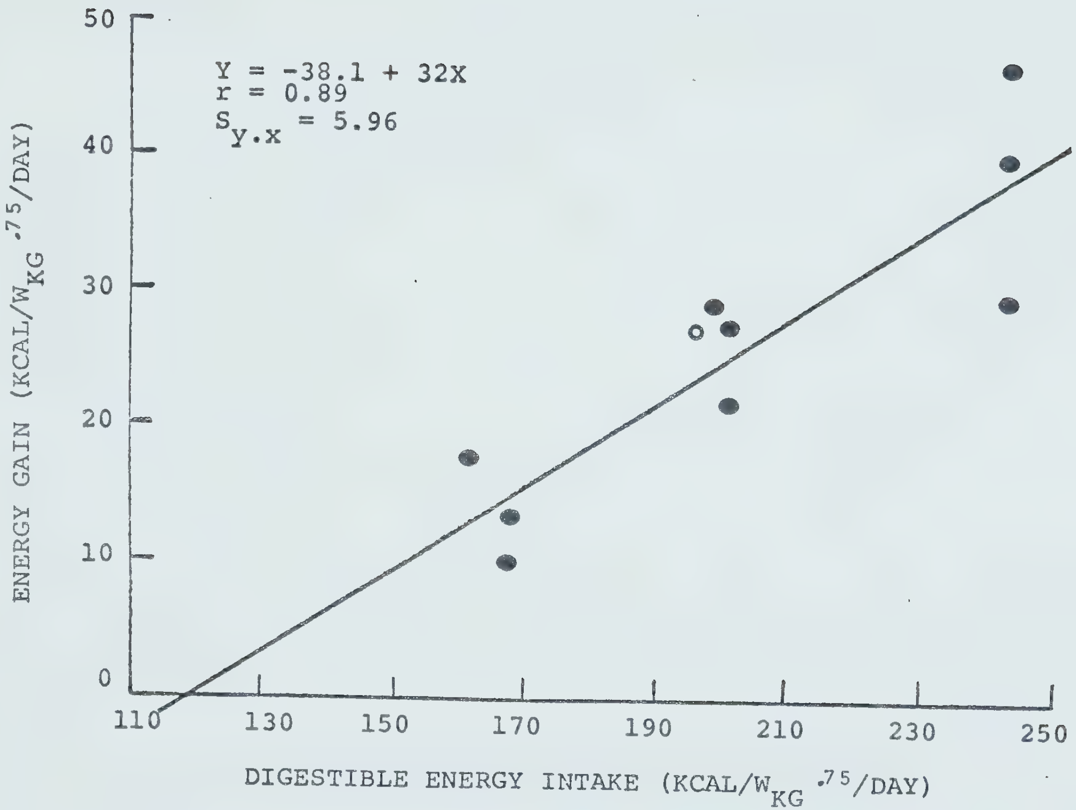

Figure 2. The relationship between energy gain and digestible energy intake during 1973-1974 winter feeding period. Each point represents data from two steers. The circle (o) value is an average value for the 25% straw group and was not considered in the regression equation.

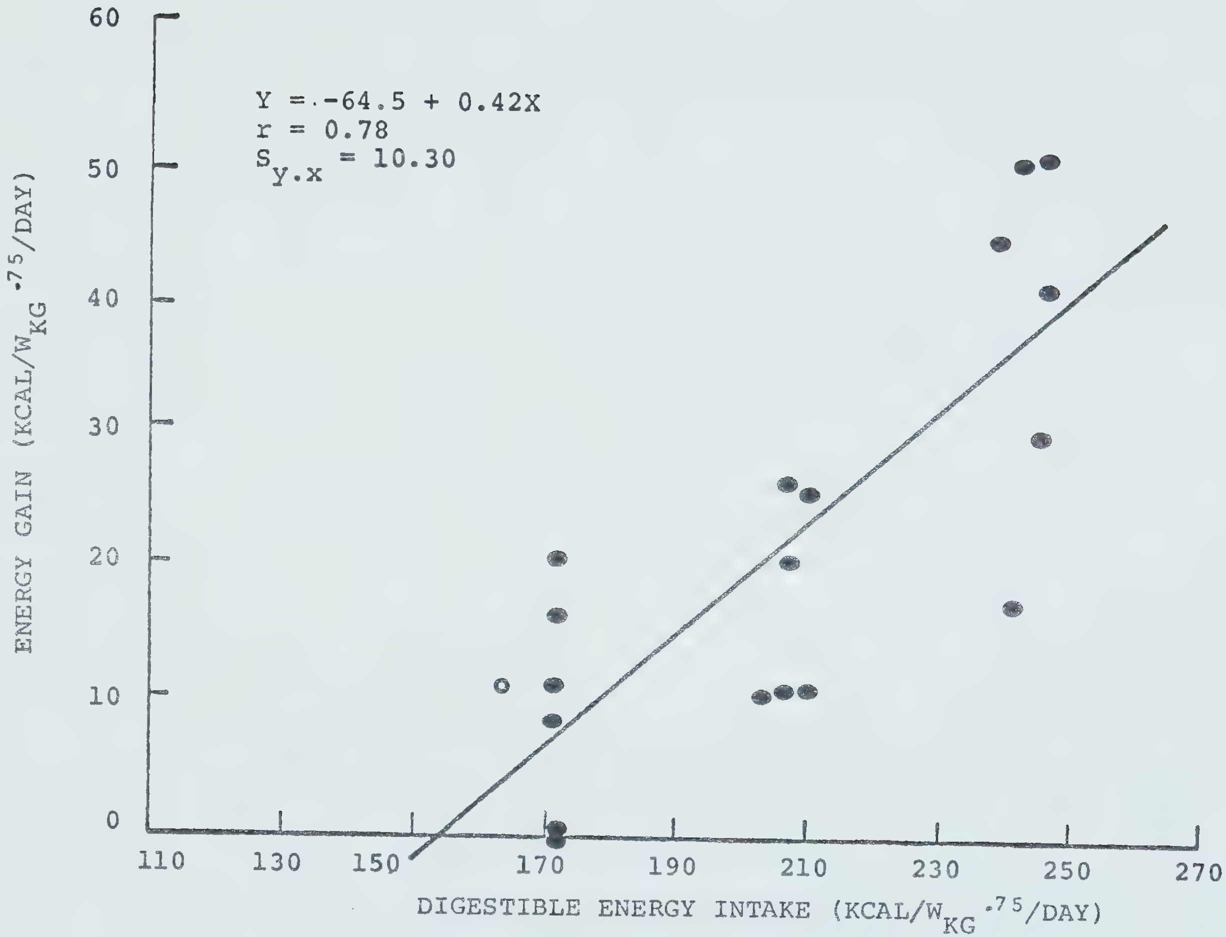

Figure 3. The relationship between energy gain and digestible energy intake for individual steers during the 1974 summer. The circle (o) value is an average value for the 25% straw group and was not considered in the regression equation.

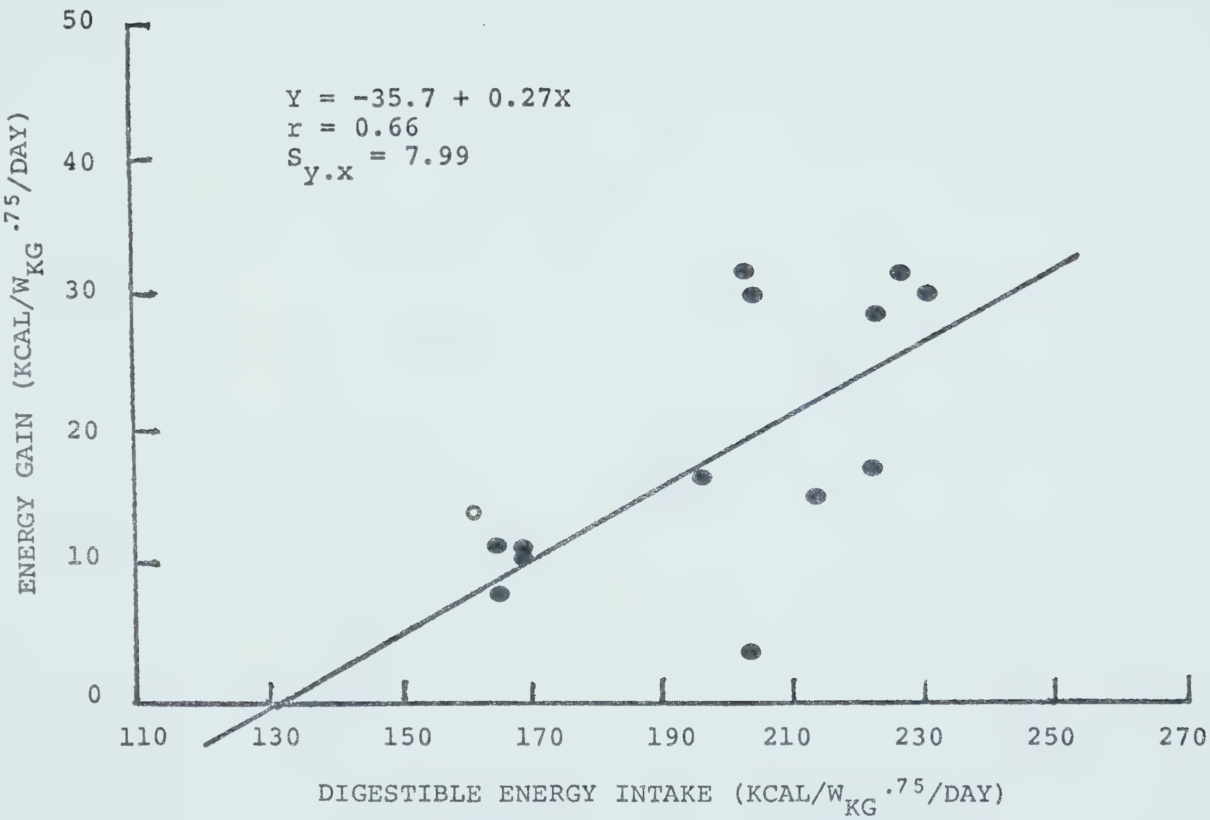

Figure 4. The relationship between energy gain and digestible energy intake for individual steers during 1974-1975 winter. The circle (o) value is an average value for the 25% straw group and was not considered in the regression equation.

determined by simple linear regressions and the results are presented in Table 8. These equations were derived by using a constant value of 78.5% digestibility of energy in the all-concentrate diet which was the value obtained for the 1.4 times maintenance feeding level in both years. The relationships show that the 1973 summer steers, 1973-1974 winter, 1974 summer and 1974-1975 winter steers gained an extra 0.08, 0.06, 0.08 and 0.10 g, respectively, of liveweight per kg$^{.75}$ for each additional kcal/kg$^{.75}$ of digestible energy provided above maintenance. Steers in the 1973-1974 winter thus gained less ($P<0.05$) and steers in the 1974-1975 winter gained significantly more ($P<0.05$) than those in the other two seasons for an equal increment of digestible energy above maintenance (Table 8).

3.9 Relationship between digestible energy intake and energy gain

There was a high degree of correlation between energy gain (kcal/kg$^{.75}$/day) and digestible energy intake (kcal/kg$^{.75}$/day) (Figures 1-4). Regression equations obtained for the four seasons were:

Summer 1973: $Y = -48.3 + 0.37X$, $r^2 = 0.90$, $S_{y.x} = 5.93$

Winter 1973-1974: $Y = -38.1 + 0.32X$, $r^2 = 0.79$, $S_{y.x} = 5.96$

Summer 1974: $Y = -64.5 + 0.42X$, $r^2 = 0.61$, $S_{y.x} = 10.30$

Winter 1974-1975: $Y = -35.7 + 0.27X$, $r^2 = 0.44$, $S_{y.x} = 7.99$

where X = digestible energy intake in kcal/kg$^{.75}$/day and Y = energy gain in kcal/kg$^{.75}$/day. There were no significant differences ($P>0.05$) between 1973 summer and 1973-1974 winter-

fed steers in terms of the efficiency of retention of digestible energy; these steers retained 37 and 32% of their digestible energy intake above maintenance respectively, as determined by the slopes of the regression equations (Figures 1 and 2). The 1974 summer fed steers retained 42% of their digestible energy intake above maintenance (Figure 3), which was significantly ($P<0.05$) more than was retained by steers in other periods. The steers fed in the 1974-1975 winter were the least ($P<0.05$) efficient, retaining only 27% of the energy they received above maintenance in body tissues.

3.10 Estimated maintenance requirements

The X-axis intercepts calculated from the equations in Table 8 can be used to provide an estimate of the digestible energy required by these steers for zero liveweight gain (maintenance). These intercepts for the four feeding periods were 92 and 128 kcal DE/kg$^{.75}$/day for the two summers and 103 and 111 kcal DE/kg$^{.75}$/day for the winters in the two years.

The estimated amounts of digestible energy required for zero energy gain were 131, 119, 154 and 132 kcal/kg$^{.75}$/day for 1973 summer, 1973-1974 winter, 1974 summer and 1974-1975 winter,respectively (Figures 1-4). These results suggest a somewhat lower digestible energy maintenance requirement during winter; which is opposite to what would be expected.

DISCUSSION

4.1 Digestibility data

In the 1973-1974 year the digestibility of the diets tended to be relatively constant at different feeding levels, except for the lowest feeding level (1.1 times maintenance) in which digestibility coefficients were reduced (Table 4). A possible cause for this reduction may have been that a nutrient deficiency existed at this feeding level since deficiencies in protein and minerals have been shown to have a depressing effect on the digestibility of the diet (Schneider and Flatt, 1975).

There was a general trend for the digestibilities of dry matter, energy and crude protein to decrease with feeding level in the 1974-1975 year. This trend is in agreement with observations that the digestibility of feed by ruminants decreases as intake increases (Blaxter and Wainman, 1961). The magnitude of depression, while consistent with results obtained when cattle were fed roughages, was considerably greater than expected for the grains however, since there was a drop of approximately 5 digestibility units with an increase of 1.0 times maintenance in feed intake level for the all-concentrate diet. This compares to reported 1 to 3% reduction in digestibility observed with increases in feed consumption of 50 to 100% (MacDonald et al, 1969). A reduced digestibility can be explained by a faster rate of passage of ingesta which accompanies higher feeding levels (Balch and Campling, 1964) and which according to MacDonald et al (1969),

results in a shortening of the time the material is exposed to digestive enzymes in the tract.

There was a difference in apparent digestibilities and in the change in digestibility with increasing feeding levels between the two years (Table 8). There is reason to believe that the method used in 1973 was valid and the pens were scraped clean since the digestibilities would have been higher at lower feeding levels if excreta had been left on the floor after the pens were scraped. The difference in trends between the two years (Table 4) could be explained by a nutrient deficiency at low feeding levels in 1973 which would have resulted in a reduction in digestibility at these feeding levels (Schneider and Flatt, 1975). Since the apparent digestibility of the 1973 diet (excluding the 1.1 times maintenance feeding level) was significantly higher ($P<0.05$), however, this possibility is unlikely. It is thus more probable that the digestibility results obtained in 1974 and at 1.1 times maintenance level in 1973 had some degree of error involved because of the methods of collection used. The 1974 animals were restrained individually in stanchions throughout the collection period. The latter steers were also daily fitted with collection bags and were housed in a barn close to the entrance and the animals were probably disturbed each time someone entered the barn. It would thus appear that the animals used in digestibility studies in 1974 experienced disproportionately greater 'stress' than the 1973 animals (except those at 1.1 times maintenance level) and this

may have contributed to the lowering of the digestibility of 1974 diets (Church, 1971) as well as to the trend towards reduced digestibility at higher feeding levels. The 1.1 times maintenance steers, housed in individual metabolism crates, may have been similarly affected by stress.

Another and possibly more important reason for lowered digestibilities obtained in 1974 digestibility trial may have been an inadequate length of the pre-collection period since, according to Wiktorsson (1971) a great change in the feed ration one or two weeks before the collection period would result in lower digestibilities. Wiktorsson (1971), in fact, found no decreases in digestibility at high feed consumption in animals which were long-term adapted to a diet of crushed concentrate (or long hay). In our trials, the 1973 animals were the actual experimental steers and had been on the test diet for not less than 12 weeks (6 weeks for the 1.1 times maintenance level of feeding) compared to the two weeks of 'adaptation' (pre-collection) period provided the 1974 steers.

There were significant differences ($P<0.05$) in apparent digestibilities of dry matter, organic matter and gross energy of all diets between the years (Table 4), being 5 digestibility units lower in 1974 compared to 1973. The 1974 barley thus appeared to have a lower feeding value, however, as discussed above, other factors could be involved in this difference. The similarity of energy digestibilities (78.6% vs 78.3%) at the 1.4 maintenance feeding level would, in fact, suggest that apparent differences in digestibility may not

have been due to the barley. Crude fibre content of 1974 barley was slightly lower than in 1973 barley, 5.1% vs 5.5% (Table 1), and while crude protein contents were lower also (14.5% vs 12.2%), gross energy values were similar for the two years, being 4.3 and 4.4 Mcal/kg, respectively.

4.2 Usefulness of specific gravity technique

In this study the use of carcass specific gravity measurement to estimate energy composition of gain proved to be essential. This can be illustrated by the observation that steers gaining the most liveweight at the 1.7 times maintenance level of feeding did not gain the most energy (Table 5 and 6).

The carcass specific gravity technique of estimating empty body energy content appeared to be more useful for fatter animals than for thinner animals since significant differences were found in carcass specific gravities between steers fed at the 1.7 and 2.0 times maintenance feeding levels whereas no significant differences were observed between the initial slaughter group and the steers fed at 1.4 and 1.7 times maintenance in all the four seasons (Tables 3 and 6). The lack of significant difference in specific gravity between the thinner groups of steers could be partly attributed to the relatively slower accumulation of fat in immature animals (Berg and Butterfield, 1976). It has, however, also been shown that the specific gravity technique lacks precision for leaner animals (Reid and Robb, 1971) and this is particularly true for cattle containing less than

30% fat (Gill *et al*, 1970).

In this study the average percent fat in the empty body of steers in the initial slaughter groups were 16% (1973 summer), 13% (1973-1974 winter), 17% (1974 summer) and 14% (1974-1975 winter). One steer in the 1974 summer initial slaughter group and three in each of the other three seasons contained less than 14% empty body fat. Several of the animals thus fell outside of the range of 14-36% empty body fat which was the range in fatness of 48 steers used by Garrett (1968) in deriving the equations used in this study.

Garrett and Hinman (1969) considered the use of six animals per treatment to be adequate in using carcass specific gravity techniques to estimate body composition. The lack of significant differences in carcass specific gravities in this study between lean animals fed at different feeding levels, however, suggests that either more animals should have been included in the groups fed at lower feeding levels or that fatter animals should have been used.

4.3 Actual and predicted rates of gain

In this study steers tended to gain more weight than was predicted on the basis of CNES (Table 7). This is in general agreement with results of a 20-month study with feedlot cattle in Colorado discussed by Knox and Handley (1973) and analysis of seven years of monthly feedlot performance records by Milligan and Christison (1974) in Saskatchewan, who have also shown that liveweight gains tend to be underpredicted by the CNES. In neither of these two studies,

however, was the actual composition of the liveweight gain investigated.

In the present experiment, although steers gained more weight than predicted by the CNES, the actual energy gains (Mcal/day) were less ($P<0.01$) than predicted by the same system in the case of 1973 and 1974 summer and 1974-1975 winter steers fed all-concentrate diets (Table 7). While the daily energy gains were higher than predicted for steers fed the 25% straw diets in the summer and winter of 1973 (Table 7), they were not significantly ($P>0.05$) so. This means that the steers in this study tended to deposit energy in a less concentrated form than expected for animals in California of similar liveweights. The 129 steers used in the current study had 20.4 ± 9.4 percent empty body fat at slaughter. Similar information is unavailable for steers used in the derivation of the CNES; however it is probable that the cattle used in California were earlier maturing than those used in this study. This would predispose the CNES toward underpredicting the weight gains in the steers in Alberta if the current experimental animals could be considered representative of Alberta cattle.

4.4 Utilization of energy for gain

An energy digestibility of 78.5% was obtained at 1.4 times maintenance in both years. This value was used in calculating the efficiency of energy retention (Figures 1-4) and in deriving a relationship between weight gain and energy intake (Table 8) and is in line with the standard practice of

using a constant ME value obtained at one feeding value in energy retention experiments.

Ørskov has pointed out that the depression in digestibility which occurs with increasing feeding level is compensated by decreasing energy losses in methane and urine and thus calculated metabolizable energy values based on digestibility determined at maintenance would be reasonably accurate (Denissov, 1969). Nehring and Schiemann (Rostock researchers) have strongly recommended the use of DE coefficients which have been obtained at the maintenance level (Denissov, 1969). Thus the use of a constant DE value in this study obtained at a level closest to maintenance (1.4 times maintenance) was considered acceptable in assigning DE intakes for the steers in examining the utilization of energy for gain.

Efficiencies of retention of energy for liveweight and energy gain (Table 8, Figures 1-4) were calculated using digestible energy values rather than calculated metabolizable energy intakes. In the many trials in which energy retentions have been measured, ME values have generally been obtained by multiplying DE intakes by a constant factor of 0.82 (NAS-NRC, 1970), which assumes that urinary and gaseous losses are a constant proportion of digestible energy. This is not correct (Blaxter and Wainman, 1961; Kromann, 1973) particularly for high concentrate diets.

It has been suggested that at low levels of feeding, maintenance energy requirements are higher in the winter than

in the summer (Smith *et al*, 1971; Young, 1975b). It has, also been suggested that winter has very little effect on feedlot performance of animals fed *ad libitum* (Webster, 1970) and thus it would appear that energy retention in animals on full feed in winter should not be significantly different from that in the summer. If both of these concepts are valid then the efficiency of energy utilization in the winter, as determined from the slope of a regression between energy gain and energy intake, will be steeper in winter than in summer indicating a greater efficiency of energy retention for gain in the winter. This, however, was not found to be the case in the present study since non-homogenous regression coefficients ($P<0.05$) (Figures 1-4) indicated that steers fed in the 1974-1975 winter were the least efficient in converting digestible energy intake above maintenance into empty body energy gains and the other winter-fed group was the next least efficient, although the latter group did not differ significantly ($P<0.05$) from one of the summer groups (1973). It is thus apparent that either maintenance energy requirements of steers at low level of feeding were not increased in the winter, or the steers at higher feeding levels were adversely affected in the winter or, that other factors were more important than environment in affecting the apparent efficiency of energy utilization for gain as determined in this experiment.

Garrett *et al*, (1964) have found differences in efficiency of use of energy for gain with similar

cattle fed similar feeds in two different environments. In their experiment the net energy for gain (NEg) value calculated from groups of cattle fed at maintenance and <u>ad libitum</u> decreased by 23% when steers were exposed to adverse weather conditions, when 21.6 cm of rain fell during the latter part of the trial resulting in muddy corrals. These conditions were accompanied by an 18% reduction in feed consumption from a comparable period before the rains. There was thus good agreement between our results and their results. Other researchers (Knox and Handley, 1973; Milligan and Christison, 1974; Young and Christopherson, 1974) have also presented data which suggests that steers fed <u>ad libitum</u> are adversely affected by winter cold.

The winter-fed steers in the present experiment deposited less of their energy in the form of fat than the summer-fed steers (Table 6), possibly because of a lighter average liveweight in the 1974-1975 winter steers and because of a low initial fat content in the 1973-1974 winter steers. The percentage efficiency of use of DE intake above maintenance for liveweight gain (Y) was related ($P<0.05$) to the percentage of energy retained as fat (X) according to the equation $Y = -26.25 + 0.77X$ ($r^2 = 0.90$). There are other reports in the literature where a positive relationship between the proportion of fat synthesized and the efficiency of use of energy above maintenance has appeared (Garrett <u>et al</u>, 1964; Bull <u>et al</u>, 1970; Garrett, 1971; Garrett <u>et al</u>, 1976). A summary of data does, in fact, suggest that an animal may

require 1.5 times more energy to deposit energy as protein than to deposit energy as fat (Buttery and Boorman, 1976). It has also been suggested that animals synthesizing more protein may have a higher maintenance requirement than animals synthesizing predominantly fat (Kielanowski, 1976). The major factor influencing the efficiency of energy use for gain in this experiment may thus have been the type of tissue formed. It is thus difficult to draw valid conclusions concerning the effect of environment on the efficiency of energy retention from these results.

Any relationship between efficiency of energy deposition and the type of depot tissue formed would mean that a single NEg value would not describe the nutritive value of a feedstuff adequately for animals of various weights and at various feeding levels. Since low energy feedstuffs tend to cause lower average daily gains, and thus a smaller proportion of fat synthesis, such a relationship could also explain why the NEg values of such feeds are relatively low.

Actual energy retained (kcal/kg$^{.75}$/day) for the straw-fed steers was 32.9, 28.1, 10.2 and 12.3 for the 1973 summer, 1973-1974 winter, 1974 summer and 1974-1975 winter steers, respectively (Table 6). These values are slightly higher than the values predicted from the regression equations derived for all-concentrate diets (Figures 1-4) of 19.4, 27.8, 5.6 and 7.8 respectively. This suggests that the addition of roughage to the diet may have compensated for any decreased efficiency of use of digestible energy which would be

expected when straw is fed (Wise et al, 1967; Hogkins et al, 1969).

4.5 Effects of season on composition of gain

In this experiment, the summer-fed steers deposited more of their energy as fat compared to the winter-fed steers. Thus 33-50% of the empty body weight gain in the summer-fed steers was in the form of fat and 20-37% of the weight gain in the winter-fed steers was fat (Table 6). This occurred when actual mean empty body weight gain ($g/kg^{.75}/day$) was greater in the two winters compared to the two summers, 7.3 ± 2.8 g vs 6.3 ± 3.5 g, respectively (Table 6). This pattern of gain in addition to being caused by environment, could possibly also be attributed to a lighter average live-weight in the 1974-1975 winter steers and a low initial fat content in the 1973-1974 winter steers. Kromann et al, (1971) found that the body composition of lambs was independently influenced by environment and level of energy intake; the carcasses of lambs fed high-energy ration in the semi-closed barn were 'fatter' than carcasses of lambs kept in the open barn. Young (1975a) reported short-term weight losses in cattle on exposure to cold and weight gains with abrupt removal of cold stress. These changes were found to have been associated with changes in water intakes and apparent shifts in body fluids, factors that would greatly affect composition of the gain and could conceivably adversely affect the weight gain of cattle in the winter.

4.6 Effects of environment on animal performance

The steers in the present study gained considerably more weight in summer of one year (1973) and in winter of another (1974-1975) ($P<0.01$) than predicted by the CNES (Table 7). Thus no major effect of environment on the differences between actual and predicted rates of liveweight gain was observed in the present experiment; neither did environment have any consistent effect on the amount of energy retained (Table 8). These results are in contrast to studies comparing winter outdoor and indoor performance of sheep (Webster et al, 1969) and of steers (Hidiroglou and Lessard, 1971) which have shown that the inside (or sheltered) animals gained 62% (sheep) and 30% (steers) more in body weight than outside (or unsheltered) animals in the winter. In a recent study Gonyou (1977) also reported a reduced efficiency of steers in an outdoor winter environment as compared to indoor steers as measured by average daily liveweight gain. A 16% and 25% reduction in feed efficiency (Self et al, 1963; Bennett and O'Mary, 1965) has been measured in cattle kept outdoors vs those kept indoors. No explanation is readily apparent for the differences obtained between our study and those in the literature. It may well have been that the experimental design in this study was not sensitive enough to detect differences in animal performance since different animals were used for each season and since it has been shown above that composition of gain is very important in determining efficiency of energy retention (Section 4.4).

4.7 Extrapolated maintenance requirements

Extrapolated maintenance requirements, as obtained in this study, must be compared with caution, since any tendency towards a curvilinear response in energy retention at feeding levels above maintenance, would bias results. No such tendency, however, could be detected in the present results.

Extrapolated maintenance energy requirements (x-axis intercept) based on energy retentions were higher in the 1974 summer season than in the two winter seasons (Figures 1-4). Also the steers fed in the 1973-1974 winter appeared to have the lowest maintenance requirement (Figures 1-4). There was thus no evidence in this experiment for increased maintenance requirement of feedlot steers in the winter even though animals at low feeding levels supposedly have increased maintenance requirements in the winter (Hidiroglou and Lessard, 1971; Young 1975b). There were, however, many winter days during which the mean temperature was above -20°C (Table 2) which is considered the approximate lower critical temperature below which an animal at maintenance would need to increase its heat production and hence its energy requirements in order to maintain body temperature (Webster, 1970). Indeed, it would appear that there are few days in the average winter in Edmonton in which the mean daily temperature is below -20°C.

It has been shown that the digestibility of energy in the diet is reduced in the cold (Young and Christopherson, 1974; Christopherson, 1976). This would also tend to increase the estimate of maintenance requirements. It has, however,

also been shown that the amount of energy lost as methane also falls at colder temperatures (Kennedy and Milligan, 1978) and thus, these two factors would tend to cancel each other.

SUMMARY AND CONCLUSIONS

Steers were fed an all-concentrate diet at three or four different feeding levels above maintenance in two consecutive summer and winter feeding periods to evaluate the effect of a cold environment on the application of CNES to feedlot cattle. Steers gained more weight than was predicted on the basis of CNES even though the actual energy gains were less than predicted by the same system, indicating that the steers in this study tended to deposit proportionately less fat than expected for animals with liveweights between 243 and 368 kg. No major effect of environment on the differences between actual and predicted rates of liveweight gain was observed; steers gained 0.17 ± 0.01, 0.03 ± 0.02, 0.06 ± 0.02 and 0.15 ± 0.03 kg per day more than predicted in 1973 summer, 1973-1974 winter, 1974 summer and 1974-1975 winter, respectively. Thus the environment did not have any consistent effect on liveweight gain.

The efficiency of retention of digestible energy when all-concentrate diets were fed was 32 and 27% for the two winter feeding periods and 37 and 42% for the summer periods. However, it could not be concluded that energetic efficiency was reduced in a cold environment since the summer-fed steers deposited more of their energy as fat than the steers fed in the two winters.

The efficiency of retention (%) of the digestible energy intake above maintenance in liveweight gain (Y) was significantly ($P<0.05$) related to the percentage of energy retained as fat (X) according to the equation: $Y = -26.25 + 0.77X$,

($r^2 = 0.90$). This suggests that NEg values for feedstuffs are not constant (as is assumed in the CNES) but are dependent on the type of depot tissue formed and thus upon the physiological age of the animal and the feeding level.

No evidence was obtained to indicate increased maintenance energy requirements for feedlot cattle under winter conditions in Alberta. Estimated maintenance requirements in this experiment were, however, obtained by extrapolation from results obtained with steers fed above maintenance. Such animals would be expected to be affected by a cold environment to a lesser extent than cattle fed at maintenance.

Steers provided with approximately 25% of their feed intake as wheat straw gained slightly more energy (approximately 8 kcal/$kg^{.75}$/day) than those fed an all-concentrate diet at comparable intakes suggesting that the addition of roughage to steer diets was beneficial. The average daily gains were approximately 10% more than the values predicted by the CNES; however no significant improvement in rates of gain and feed efficiencies due to feeding straw was detected in any of the feeding periods except possibly in the summer period of 1973.

The results of this study confirm previous observations that the CNES under-predicts liveweight gains in cattle in Western Canada. It was also shown that the system over-predicts energy gains. Differences in efficiencies of energy retention were observed in this study and were related to

either the type of depot tissue formed, or the environment or both. This indicates that the CNES has some limitations under Alberta conditions. Further work is required to more specifically determine what these limitations are in order to be able to develop more accurate predictions of animal performance and to be able to evaluate feedstuffs more accurately.

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APPENDIX TABLE 1a

Means and standard deviations of feedlot performance data and carcass characteristics of six experimental steers feeding at 1.1 times maintenance level in 1973 summer.

	Means	S.D.[1]
Dry matter intake ($g/kg^{.75}/day$)	38	1.2
Digestible energy intake[2] ($kcal/kg^{.75}/day$)	128	3.9
Initial weight (kg)	302	16.5
Final weight (kg)	324	16.9
Daily gain (kg)	0.14	0.13
Daily feed intake[3] (kg)	3.4	0.08
Feed/gain[3]	24.1	6.3
Warm carcass weight (kg)	173	9.5
Dressing %	53.4	1.11
Fat depth (mm)	6.3	1.13
Rib eye area (cm^2)	65.1	5.26

[1] Standard deviation.

[2] Obtained from measured digestibility coefficients at this level.

[3] As-fed basis.

APPENDIX TABLE 1b

Means and standard deviations of empty body composition and gain of six experimental steers feeding at 1.1 times maintenance level in 1973 summer.

	Means	S.D.[1]
Carcass specific gravity	1.077	0.006
Initial empty body weight (kg)	258	14.1
Initial empty body fat (kg)	42	2.3
Initial empty body energy (Mcal)	649	35.4
Final empty body weight (kg)	266	13.0
Final empty body fat (kg)	39	10.7
Final empty body energy (Mcal)	638	102.5
Gain empty body weight ($g/kg^{.75}/day$)	0.72	1.54
Gain empty body fat ($kcal/kg^{.75}/day$)	-1.95	7.11
Gain empty body energy ($kcal/kg^{.75}/day$)	-1.06	8.52
Energy gain as fat (%)	-183	

[1] Standard deviation.

APPENDIX TABLE 2

Means and standard deviations of apparent digestibilities (%) of dry matter, gross energy, crude protein and organic matter of all-concentrate diet offered at 1.1 times maintenance level of feeding in 1973 summer.

	Means	S.D.[1]
Dry matter	72.3	3.74
Gross energy	73.3	3.63
Crude protein	73.2	6.41
Organic matter	76.3	3.15

[1] Standard deviation.

APPENDIX TABLE 3

Analysis of variance mean square and F values for liveweight, carcass data and empty body parameters for the initial slaughter groups.

Source of error	M.S.[1]	F.[2]
Liveweight (kg)	9734	14.29***
Carcass specific gravity	0.0001	1.70
Warm carcass weight (kg)	3212	13.69***
Dressing %	3.288	0.60
Empty body weight (kg)	5964	13.71***
Empty body fat (kg)	233.4	2.06
Empty body energy (Mcal)	37278	3.36**
Empty body energy/kg liveweight (Mcal)	0.141	1.41
Empty body weight/kg liveweight (kg)	0.001	0.61
Empty body fat/kg liveweight (kg)	0.002	1.42

[1] Mean square value.

[2] F value

*Indicates significance P<0.10.

**Indicates significance P<0.05.

***Indicates significance P<0.01.

APPENDIX TABLE 4

Two-way ANOVA on the effect of level of feeding and years on the apparent digestibilities of dry matter, gross energy, crude protein and organic matter of diets offered.

	Dry matter		Gross energy		Crude protein		Organic matter	
Source of error	M.S.[1]	F.[2]	M.S.	F.	M.S.	F.	M.S.	F.
Feeding level (F)	117.0	24.21***	134.2	28.26***	151.0	31.01***	38.96	2.81*
Year (Y)	177.1	36.63***	142.3	29.97***	189.1	38.82***	264.1	19.08***
Interaction (FY)	18.09	3.74**	16.18	3.40**	13.17	2.70*	13.84	0.48

[1] Mean square value

[2] F value

*Indicates significance at P<0.10.

**Indicates significance at P<0.05.

***Indicates significance at P<0.01.

APPENDIX TABLE 5

Analysis of variance mean square and F values for feedlot performance data and carcass characteristics of experimental steers.

	All-concentrate diets (times maintenance)								25% straw diets	
	1.4		1.7		2		ad libitum			
Source of error	M.S.[1]	F.[2]	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.
Dry matter intake ($g/kg^{.75}/day$)	0.333	0.31	1.111	1.33	22.44	117.9***	7280	352.3***	69.42	21.36***
Digestible energy intake ($kcal/kg^{.75}/day$)	37.68	4.97**	78.26	8.64***	1211	646.0***	4931	2889***	1257	41.58***
Initial weight (kg)	4022	110.0***	3676	128.2***	4014	191.6***	7280	352.3***	3635	37.77***
Final weight (kg)	5866	216.9***	5726	162.4***	9976	128.4***	27068	55.77***	8040	40.40***
Daily gain (kg)	0.006	1.87	0.028	19.58***	0.031	6.82**	0.282	6.91*	0.090	9.66***
Daily feed intake (kg)	0.496	260.8***	0.694	208.3***	2.381	832.5***	-	-	2.732	409.8***
Feed/gain	8.823	2.74	13.09	34.75***	5.026	12.30***	-	-	48.05	7.40**
Warm carcass weight (kg)	2570	69.72***	2875	80.79***	4796	195.2***	8588	53.36***	3694	65.09***
Dressing %	15.60	10.94***	19.60	13.18***	15.63	35.60***	0.007	0.04	11.16	16.11***
Fat depth (mm)	16.92	4.30*	43.33	5.89**	70.30	18.59***	63.38	10.61**	39.13	23.54***
Rib eye area (cm^2)	175.7	8.10**	86.82	4.03*	47.71	8.74**	24.00	1.74	193.6	6.55**

[1]Mean square value.

[2]F value

*Indicates significance at P<0.10.

**Indicates significance at P<0.05.

***Indicates significance at P<0.01.

APPENDIX TABLE 5

Analysis of variance mean square and F values for feedlot performance data and carcass characteristics of experimental steers.

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	1.4		1.7		2		ad libitum			
Source of error	M.S.[1]	F.[2]	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.
Dry matter intake ($g/kg^{.75}/day$)	0.333	0.31	1.111	1.33	22.44	117.9***	7280	352.3***	69.42	21.36***
Digestible energy intake ($kcal/kg^{.75}/day$)	37.68	4.97**	78.26	8.64***	1211	646.0***	4931	2889***	1257	41.58***
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Rib eye area (cm^2)	175.7	8.10**	86.82	4.03*	47.71	8.74**	24.00	1.74	193.6	6.55**

[1]Mean square value.

[2]F value

*Indicates significance at P<0.10.

**Indicates significance at P<0.05.

***Indicates significance at P<0.01.

APPENDIX TABLE 6

Analysis of variance mean square and F values for empty body composition and gain of experimental steers

	All-concentrate diets (times maintenance)								25% straw diets	
	1.4		1.7		2.0		ad libitum			
Source of error	M.S.[1]	F.[2]	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.
Carcass specific gravity	0.0001	4.0*	0.0001	3.71*	0.0002	9.43***	0.0005	27.19***	0.0001	10.48***
Initial empty body weight (kg)	212.5	100.0***	2462	116.3***	2509	186.3***	4953	325.3***	2287	34.80***
Initial empty body fat (kg)	155.2	213.1***	137.1	271.7***	124.8	356.4***	410.9	1139***	132.4	97.56***
Initial empty body energy (Mcal)	21357	157.9***	20287	156.1***	18642	218.5***	12725	32.31***	19243	52.94***
Final empty body weight (kg)	4441	29.12***	5344	83.64***	8831	183.5***	15967	52.26***	6627	66.40***
Final empty body fat (kg)	327.0	15.90***	473.7	14.61***	1614	16.66***	4464	42.01***	1049	51.89***
Final empty body energy (Mcal)	43574	19.59***	69658	23.94***	18990	25.37***	500765	45.05***	134383	92.15***
Gain empty body weight ($g/kg^{.75}/day$)	6.450	5.46**	4.242	9.04***	5.490	14.86***	0.3361	0.09	12.37	12.65***
Gain empty body fat ($kcal/kg^{.75}/day$)	19.80	1.44	40.94	0.97	276.3	4.41**	991.2	7.22*	332.2	13.92***
Gain empty body energy ($kcal/kg^{.75}/day$)	14.50	1.09	53.37	1.45	199.4	3.64*	1863	12.94**	383.1	21.13***

[1]Mean square value.

[2]F value
*Indicates significance at P<0.10.
**Indicates significance at P<0.05.
***Indicates significance at P<0.01.